INLAND NAVIGATION
ON
THE GANGETIC RIVERS

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WITH MAP
SHOWING NAVIGABLE WATERWAYS OF THE GANGETIC PLAIN.

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Dehra Dun,
30th January, 1946.

FOREWORD

The question of the utilisation of the Gangetic rivers for inland navigation and water transport has from time to time aroused interest in recent years. More specifically it has come to the fore in connection with post-war schemes for the development of Indian industry.

The subject is of great national importance. The restricted capacity of Indian railways was one of the most hampering factors in the range of supply problems during the second world war, and it is generally recognised that had there been in existence a commercially developed water transport system at the beginning of the war, or if one could have been subsequently organised, many supply problems would have been considerably eased, if not solved altogether.

The importance of water transport is not however confined to wartime conditions alone. It is of even greater importance as a factor in the industrial development of the Gangetic valley. In this sphere, in fact, it can without exaggeration be deemed essential.

Few people, however, have more than a vague idea of the conditions requisite for the development of a modern water transport system, or how far these conditions are met on the rivers of the Gangetic plain. I believe that at the present time many commercial men, politicians and economists would welcome more specific information on the subject. Commercial navigation, however, particularly in its inland form, covers a wide diversity of subjects, such as transport economics, river conservancy, naval architecture and constitutional law (to name only some), the separate study of which would be for the average layman an insuperable task. Hence the need for a simple, yet comprehensive treatise such as has not hitherto been anywhere available.

It is with a view to assisting those who are interested but have hitherto had no means of getting such comprehensive information that this book has been attempted.

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CHAPTER I

THE ECONOMICS OF WATER TRANSPORT

The economics of transport are, in the main, simple. The chief factors are bulk and speed. In short, the problem is to carry a given bulk a given distance in a given time.

This may be illustrated by a simple example. Suppose we are required to transport a thousand tons of coal fifty miles, delivery to be made in ten days. There are two ways in which we could do this. We could either transport 100 tons per day for ten days, or we might ship the whole 1,000 tons at once and take ten days over the journey. In either case the conditions of delivery would be satisfied.

From this we can see that speed of transport makes up for lack of bulk, and *vice versa.* Naturally the question which method we adopt depends upon the type of transport at our disposal. If the two places are linked by a railway the obvious thing is to dispatch the coal by rail, the bulk dispatched at one time and the ultimate date of delivery being dependent on the number of trucks from time to time available. We might quite well be able to send the whole lot in one trainload, or, if that were not possible, then at least an average of five 20-ton wagons each day for ten days would be necessary. If there is no railway, but the places are linked by road, and we have at our disposal a fleet of, say, 20 five-ton lorries we could still dispatch our 100 tons a day. Lastly, supposing the two places are on the sea coast or linked by navigable waterway, we could load the whole consignment into a ship or barge which might reasonably be expected to deliver it within ten days in even the worst conditions of navigation.

Should we have more than one means of transport at our disposal, it would be necessary to decide which we proposed to adopt. At first sight it might appear that we would plump for that mode of transport which advertised the cheapest freight rates. Rates of freight however are not nearly so important as might at first sight appear. In cases where there is a choice between different forms of transport, the decision which is most economical depends upon other more important factors. Of these, the first two are the nature of the cargo and urgency with which it is required. For example, quickly perishable goods require to be sent by the quickest form of transport, regardless of cost. Other classes of

goods, such as *ata* or other cereal preparations, though not perishable to the same extent, are nevertheless liable to deterioration from prolonged transport. It may even pay in some cases to transport non-perishable goods, such as cement or coal, by the quickest rather than the cheapest route, in order, for example, to avoid stoppage of building construction or factory output. Considerations of urgency may, and frequently do, apply in the case of commodities, such as grain, in which fluctuation in market prices between date of despatch and date of delivery would mean loss either to consignor or consignee.

Outside these special considerations, there are other factors inherent in the transport system itself. These are deterioration or damage caused by the method of transport (apart from that caused by delay), pilferage, loss due to leakage or damage to containers in handling, and reliability of service. In Europe and the U.S.A., for example, the furniture removal trade is almost entirely carried on in specially constructed road vans in charge of trained packers. This is because wagon shunting during rail transit and handling by inexperienced labour at the goods yards usually entails damage to such an extent as to make transport by rail unsatisfactory. Goods transported in India by country boat are often liable to damage by leakage of the vessel, thus making the majority of consignors prefer the railway though freight rates may be the same or even cheaper for water transport.

It would however be a mistake altogether to neglect freight rates as a factor. Where freight rates are, relatively to the value ot the commodity, excessively high by any form of carriage, the commodity ceases to. be transported at all. Mirzapur stone, for example, used to be a considerable item in the river transport of the Gangetic plain, but now that cheap cement concrete is available, the carriage of sandstone over all but the shortest distances is out of the question. It is however still transported in special cases as, for example, where, for reasons of sentiment or religion, it is considered essential, e.g. for gravestones or for temple construction. In the fodder famine of 1929-30 hay was transported from the Jhansi forests to Muttra and the surrounding districts. In spite of a substantial rebate in freight rates, the cost on delivery was such that, though cattle were starving, the hay had a much smaller market than was expected. In normal times the freight rates over the distance would render the transport of hay quite impracticable. The transport of mangoes to England by air is at present too costly to permit anything more than a restricted trade. Freight rates, therefore, do appear as an element

of importance in certain cases. Their importance is, however, not so great as that of other factors. We shall return to the question of freight rates later.

The main factor in transport is reliability. By reliability is meant chiefly capacity to maintain steadiness of flow. As pointed out at the beginning, bulk and speed are the main inter-related factors, and where there is no special urgency, the actual time taken in transport is of little account provided that increased time is compensated for by increased bulk. If a factory, for example, requires a hundred tons of raw material per day, it can arrange to receive that material either in separate consignments of 100 tons daily or in single consignments of 700 tons each week. The main thing is that the consignments should arrive with unfailing regularity. The same consideration applies, though to a less extent, in the case of commercial trade dumps established at big trading centres along the line of communication where goods are collected either for export overseas or for distribution in the surrounding areas. The rate of inflow and outflow in such cases should roughly balance, so that there may never be at the trade dump congestion at certain times and deficiency of stock at others.

Steadiness of flow is affected when the transport arrangements are unreliable. This is generally the case with country boat transport, when whole fleets may be held up for an indefinite period by flood conditions or by adverse winds. Steadiness of flow also depends to an equal extent on the availability of goods and the organisation behind their collection and distribution. Certain goods form seasonal traffic only e.g., rice and cotton. Others are to a certain extent seasonal, such as timber and sugar, while a third class of goods, e.g., steel and manufactured goods generally, is produced at a uniform rate throughout the year. In the case of foodgrains production is seasonal ; consumption is uniform throughout the year. The same applies to most raw materials of manufacture (a notable exception being sugarcane). In the case of all seasonal commodities, if the requirements of trade dictate a uniform flow, the success of the transport system will depend on how efficiently it can link storehouses or dumps to production centres, or, in case of oversea export or where the main storage centres are in the areas of consumption, whether the transport system can be depended upon to maintain regularity of flow in conditions of increased or decreased tempo resulting from seasonal fluctuation in supply.

Assuming that we have equipment and organisation on the rivers to meet the above requirements satisfactorily, the question

of actual rates of carriage can be considered. In general it may be accepted that for a given transport system the greater the bulk transported at one time, the cheaper will be the actual freight cost per ton. In dealing with water transport, particularly inland water transport, it is to be realised that speed in miles per hour must of necessity be very much slower than any system of land transport. As against this, modern equipment in water transport is ideally suited for handling bulk cargoes. Moreover certain types of cargo are, by reason of their nature, more efficiently carried by boat than by rail. Examples of this are timber and oil, particularly oil of low flash point. The carriage of timber in long lengths by rail requires either a special type of bogie truck or special loading on two trucks, while oil has to be carried in special tank wagons, subject to strict precautions against leakage and fire. Special equipment and a special safety organisation entail extra cost and inconvenience both to the transport system and to consignors and consignees.

The cheapness of bulk carriage will be most appreciated in the case of that class of goods in which the cost of production is small compared with the cost of transport. Such commodities are numerous, limestone and cement being only two outstanding examples. It is in these special classes of cargo that water transport has its best opportunities. But in order that the best advantage be taken of the factors on its side, it is essential both that the bulk carried should be as large and the speed of the vessel as great as possible. There are, however, in practice, limitations to bulk and speed. The main limiting factor is depth of water ; another is width of channels, though this factor will appear in practice only in certain areas of the Gangetic system, notably the Sunderbans. Limitations of draft and beam naturally impose a limit on the length of barges ; and this, inturn, as will be explained in a later chapter, imposes a limitation on speed, since, for technical reasons, length and speed go hand in hand. On the economic side the main limiting factor is availability of cargo.

So far we have been discussing only those cases in which a single transport system connects the places of loading and delivery. This, however, rarely occurs. In practice, goods normally have to be transferred from one system to another ; from road to rail, for instance, or *vice versa*. Even when the goods are loaded on rail, they have sometimes to change over to a narrower or wider gauge. Such changes involve transhipment, which is one of the chief factors increasing transport costs.

It must invariably be the aim in all transport systems to cut

down transhipments. Not only is there the extra labour in the actual unloading from one system and loading on to another, but the process involves extra staff in the way of supervisors, tally clerks and other personnel on the organisational side. Lastly and most important, delivery of the consignment is delayed. There is risk of loss, pilferage or damage in transhipment, and, in the case of railways, wagons are held up at sidings during the process of making up new trains.

Few consignments nevertheless can avoid a certain degree of transhipment. Except in the case of factories which have their own sidings, goods generally have to be loaded in the first instance on to some form of road transport such as bullock carts or motor trucks. This is especially the case with agricultural produce. Road transport is fundamentally the most expensive of all, and is not economical over long distances. It therefore pays, unless the distance involved is short, to accept the cost and inconvenience of transhipment and consign on by rail or ship. Rail transport nearly always involves transhipment back again to road transport for the final part of the journey, while in the case of transport by sea, goods frequently require to be transhipped to rail, and lastly to road before they are finally delivered.

The inconvenience of transhipment can often be avoided by making it coincide with one of the necessary stages of commercial organisation. For example, cotton picked in the fields is not in a fit condition to be transported right away. It has first to be ginned, pressed and baled. The ginning or pressing factory however is rarely in a position to purchase direct from the grower, but purchases from local brokers. Also, at some stage of all distributional operations, goods must come to a clearing house of some kind for being made up into consignments for onward dispatch to the various consignees. It can, therefore, be arranged that the cotton is conveyed from the field to the broker in one stage, from the broker to the factory in a second stage ; and there after processing it is made up into consignments and, if possible, loaded direct on to the railway. Similarly in the case of timber, logs felled in the forest are usually sawn at site, and then conveyed by road to dumps at a railway siding, there to be sorted out into parcels and dispatched as required.

In a system of water transport transhipment is one of our most serious problems. Riverways have a limited range ; it is not possible to extend them to reach industrial or commercial centres as one can with roads or railways. One can of course construct navigation canals but these involve heavy capital outlay and main-

tenance charges, and their flexibility is less than that of roads or even of railways. It is clear therefore that, in the main, a river can serve only a limited area on either bank, and in general it may be accepted that the area is limited to the distance over which it is economical to employ road transport as a feeder to and distributor from the river ports.

Certain exceptions arise, and of these one may mention carriage of timber. Where timber is flotable (and here it may be remarked that many newly felled hard woods are not) or can be rafted, there is a distinct possibility of using tributaries flowing through forest areas for this purpose, and establishing timber dumps at the point of confluence with the main river. The same thing is also possible in certain cases of agricultural produce.

We may now proceed to consider the special technical requirements and limitations in inland navigation. It is, I think, easy to grasp that the first requirement is a minimum depth of water. It is not at this stage desirable to go into technicalities further than is necessary, but it may be accepted that 4 feet depth of water is the absolute minimum required for modern barge equipment. Fortunately this depth can be found over a considerable range of the Ganges-Gogra combination at all times of the year. Details will be found in the next chapter. It should however be understood that greater depth than four feet is highly desirable. No other physical factor has greater effect upon the cargo-carrying capacity of a vessel. Mr. Albert Robinson, who in 1844-47 was responsible for considerable development of steam navigation on the Ganges, in his book "Navigating the Ganges by Iron Steam Vessels"—1848, puts the case clearly as follows:—

"Again when it is considered that a steamer that can carry only itself at 2 feet 6 inches draught, shall carry 200 tons at 3 feet 6 inches, 400 tons at 4 feet 6 inches, it will be perceived that the last foot is worth the other three and a half. A consequence flowing from this is, that with the first-named draught of water, the steamer, if dependent upon freight, could only be run at a loss ; with the second, would probably pay a profit ; and with the third, would return a large profit."

Mr. A. Pointon in his monograph on Inland Navigation (1904) quotes the above and applies the same principle to cargo flats. Assuming a flat carries—

At her loaded draft of 6 feet	28,000 maunds
At a restricted draft of 5 feet she carries only	21,700 ,,
and if further restricted to 4 ft she carries only	15,350 ,,

A flat, through her draft being reduced by two feet only, thus loses nearly half her carrying capacity. In the case of engined vessels the percentage of loss is often much greater.

The next requirement is that the speed of the current shall not be excessive. Speed of current is regulated by the degree of slope of the river bed. Comparatively little slope is required to render a river unnavigable. In road transport we are accustomed to gradients of one in twenty or more ; the steepest gradient for practical purposes may be taken at about one in seven (approximately 750 feet per mile). Rail traffic generally tries to avoid traversing gradients steeper than about one in 200, or 26.4 feet per mile. Rivers are the most sensitive of all in the matter of gradient, and it has been estimated that the maximum fall permissible for a river to be used for easy navigation is 1 in 6,336 or ten *inches* per mile.

The fall of the Ganges from Allahabad to the sea is as follows—from Allahabad to Benares (139 miles), 6 inches per mile ; from Benares to Colgong (326 miles), 5 inches per mile ; from Colgong to the Bhagirathi (135 miles), 4 inches per mile ; from the delta head to Calcutta (about 200 miles) the same ; from Calcutta to the sea 1 to 2 inches per mile according to tide. The average fall over the whole reach from Allahabad to Calcutta (about 800 miles) is 4.75 inches per mile. The speed of the current has been estimated at between 1½ to 4 miles per hour in the dry season and 2 to 8 miles per hour in the rains, depending on various factors such as fall of river bed, rainfall and width of channel. In general, an average can be assumed of 3 m.p.h. in the dry season and 6 m.p.h. in the rains. Anything over 6 m.p.h. is undesirable, but speeds upto 8 m.p.h. are negotiable by modern river tugs and barges.

Later I shall have occasion to draw attention to a certain similarity of navigational conditions in the Mississippi River in the United States of America. It will, therefore, be of interest to quote the corresponding statistics for that river. The Mississippi has an average fall from Memphis to mouth (825 miles), of 4½ inches per mile, and for nearly half that distance upriver, the fall is between 1.8 and 2.57 inches per mile. I do not have statistics of fall for the St. Louis-Memphis range, but it cannot be less than the highest figure quoted above. This latter is the range which has most interest from our point of view.

Although the drainage area (12,40,000 square miles) of the Mississipi greatly exceeds that (7,52,000 square miles) of the Ganges, Brahmaputra and Meghna put together, its discharge of

water is on the average, no greater than that of the Ganges alone. The discharge of the Mississippi at Red River Landing, some 200 miles above New Orleans varies from about 2,24,000 in low water to 16,00,000 cubic feet per second in high water. The corresponding discharges of the Ganges at Rajmahal some 250 miles above Calcutta are 2,07,000 and 18,00,000 cubic feet per second. Yet of the total of 4,190 miles from the source of the Missouri to the mouth of the Mississippi, no less than 3,950 miles are navigable at certain seasons of the year, thus giving the Mississippi-Missouri river grounds for claiming itself to be the longest waterway in the world. Considering this, there seems no reason why the Ganges-Gogra should not be made navigable for a mere 800 miles or so upstream.

Width of channel is the third requirement. The minimum requirement may be placed at about 60 feet. Generally speaking, this requirement is well met in all navigable river channels of the Gangetic system. Only in certain channels in the Sunderbans is it likely to give rise to difficulty.

A fourth requirement is that the river or channel shall be reasonably free from obstructions such as hidden reefs, shoals, sunken trees, etc. and that there be no unduly sharp bends which will give rise to difficulty in negotiation by the largest vessels employed. Again, generally speaking, the navigable sections of the Gangetic rivers possess no obstructions of a serious nature ; here and there reefs of kankar exist, but in the reaches under consideration there is a sufficient depth of water to enable them to be negotiated. Bends in the deep channel have not in the past given rise to exceptional difficulty. Sunken trees occur occasionally but they are so few as to cause no difficulty in removal as they occur.

Apart from natural obstructions it is also necessary to consider artificial ones. Railway and pontoon bridges naturally come to mind. The only pontoon bridge below Bahramghat is that at Ajodhia, which takes the place of the steamer ferry in the dry season. The only low level railway bridges likely to interfere seriously with traffic are that near Kushtia at the head of the Garai distributory and the Howrah floating bridge. A pontoon bridge can be made to open, and if the Garai is to be made a key river in a navigation scheme, it should be possible to make the bridge a swing bridge, or its level can be raised.

Further navigational obstruction may occur from flotsam and jetsam (such as corpses, fishermen's nets or sunken boats) or from boat traffic. Small articles are not likely to damage the hull,

but nets and corpse shrouds may get round propellors and temporarily disable a vessel. Collision with boats may, in addition to damage sustained, lead to litigation and claims for compensation. It may be observed that the upper part of the river is undoubtedly much freer now of boat traffic than it has been for many years and legislation in respect of navigation can prevent a sudden undesirable accession of boat traffic which it would otherwise be difficult to control. The problem, however, still remains in the lower reaches.

The last requirement for navigation is reasonable stability of the river. That is to say, the river must not change its course too rapidly. Not only does this lead to uncertainty of navigable channels, with consequent risk of vessels grounding, but it also makes it impossible in certain cases to erect any permanent pier wall or goods shed since the river may, during the next rains, sweep the whole thing away, or tantalisingly remove itself to a considerable distance away from the pier. This is one of the most serious problems to be faced, particularly in the lower reaches of the river. It can be solved to a certain extent by soil conservation measures (which will be discussed in a later chapter) and by the use of prefabrication in engineering.

The above gives a very brief account of the main technical requirements. The commercial or economic ones are equally important. For an understanding of these it will be of help to give a brief description of inland navigation as it exists in various parts of the world to-day.

In general, inland waterways may be grouped into two main classes—those which are navigable by ocean-going ships, and those which are not. A number of rivers are, however, partly navigable by sea-going vessels. The outstanding example of a river navigable throughout almost its entire length by ocean-going ships is the Amazon, to the principal port of which, Manaos, ocean liners sail 980 miles from the sea, while average sized sea-going cargo vessels can proceed a further 1,186 miles upriver to Iquitos in Peru, where practically only the Andes mountains separate them from the Pacific Ocean. This astounding navigability (practically right across the broadest part of South America) is not duplicated or even approached by any other river in the world.

Another famous example is the St. Lawrence which, between Belle Isle and Montreal, a distance of 859 miles, is navigable to the largest ocean liners. After these two rivers, there is a big drop to the Rivers Plate and Parana, the latter of which is navigable to sea-going ships for 240 miles as far as Rosario. Another

example is the 96 mile range from Astoria at the Columbia River bar up to Portland, Oregon.

Rivers which are navigable over long ranges to ocean-going ships are not numerous. They can easily be recognised from an ordinary atlas, since in all cases the principal port is as far up river as can safely be navigated by sea-going ships. We have seen that transhipment is to be avoided as far as possible, and this class of river exemplifies this precept put into practice.

Moderate sized sea-going cargo ships have a draft when loaded varying from 20 to 35 feet according to size and type. The dead weight tonnage of such vessels ranges from about 4,000 to 22,000 tons. An average for this class of vessel is between 10 and 13 thousand tons with a mean draft between 25 and 28 feet. This latter figure represents the largest ship which can safely be navigated up the Hooghly as far as Calcutta.

Few rivers can maintain this depth of water for any great distance from the sea. A number of rivers, however, can be navigated over a considerable range by vessels of between 6 and 10 feet draft, which allows the ship to engage in a limited range of sea or coastal navigation in addition to her river navigation. Examples of this can be found on the China coast and on the Danube where coasting vessels trade between Budapest and Alexandria via the Dardanelles. The lower Mississippi is also an example of this. Big ships can go inland on this river as far as New Orleans, a distance of 112 miles from the sea, while tankers go to the refineries at Baton Rouge above New Orleans to load fuel oil. Above Baton Rouge for a distance of 1,100 miles up river, navigation is possible only for special types of shallow draft vessels.

The last class of river is that on which navigation is completely barred to sea-going vessels and is possible only for specially constructed craft. These are invariably of the shallow-draft barge type for goods transport and of the well known river steamer type for passenger transport. Of this type of river the Rhine is probably the best example, but there are many others in Europe —the Scheldt, the Elbe, the Vistula, the Volga and the Niemen, to name only a few. The principal port of the Rhine is Rotterdam, situated only about 20 miles from the sea on the New Waterway entrance. The river is navigable right up to Basle on the Swiss frontier. The trade upriver consists of consumer goods, oil (chiefly from America), and raw materials, principally iron ore. Downstream the cargoes are chiefly manufactured goods from the industrial areas of Western Germany. For this trans-

port special types of barges have been developed. The largest of these is over 300 feet long, of square transverse section and flat bottom, and takes up to 3000 tons of cargo on a draft of between 8 and 9 feet. Others are special tank barges into which the sea-going oil tankers pump their oil at port of discharge. These barges are principally of the "dumb" type, i.e., they are not self-propelled. Propulsion is provided by means of a special type of shallow draft but powerful tug, which can manage two, three or four barges according to load and navigational conditions.

On the Mississippi above Baton Rouge much the same sort of conditions is found. Here also we find special types of barge and propelling vessels, but the barges are somewhat different from the Rhine type owing to the cargoes being of a lighter and bulkier nature—cotton, sugar and bauxite being some of the chief. Between St. Louis and Memphis the channel is frequently as shallow as six feet ; the river is extremely winding and, to some extent, unstable. It is on this range that navigational conditions very closely resemble those on the Ganges between Digha Ghat and Goalundo. The river is paralleled by railroads throughout its length ; nevertheless there has been in recent years a continuous increase in the amount of cargo carried. Recent figures show a fiscal year's total of 2,61,277 tons of grain, 1,74,996 tons bauxite and 1,56,897 tons sugar ; a total of 5,93,170 tons.

The economic conditions on the rivers enumerated above are of two classes. The first is that prevailing, for example, on the Amazon, which flows through a country devoid of industrial development. In this case the cargoes downstream consist of raw materials or foodstuffs and the cargoes upstream of manufactured goods in exchange. The same conditions apply generally to the Rivers Plate and Parana, where the principal export is grain. The second class of river is perhaps best typified by the Rhine, which serves the Ruhr coalfield and industrial area. Here we see a reversal of the above order. The upstream cargoes on the Rhine consist chiefly of raw materials and the downstream ones of manufactured goods or coal. The Mississippi is somewhat peculiar in that both industrial and raw material producing areas are served. Generally also we find that on the first class of river transhipment is not necessary because of facility of navigation, and that navigation is not extensively plied above the limit for sea-going vessels. On the second class of river there is definite transhipment at mouth for both upstream and downstream cargoes. On the Rhine, and on the French, Belgian and Dutch canals there is, on the other hand, usually no transhipment from

road or rail at upstream port. This is because most of the industrial concerns utilising the waterways are built on the edge of the river or canal, and possess their own wharves or docks.

In this way much of the cost of transhipment is saved. Transhipment from barge to steamer or *vice versa* is in any case a cheaper proposition than from steamer to rail or rail to steamer. For the latter considerable capital expenditure is entailed in acquiring sufficient dock area, and in laying out an elaborate system of sidings. On account of the small unit represented by the average railway wagon, loading is a slow business, unless expensive modern grain or ore shoots are employed. In the case of a barge, loading and unloading can be carried out in midstream, using the steamer's own derricks, or, in the case of grain or oil cargoes, suction discharge driven by machinery carried on a special flat for the purpose.

Though economic conditions, therefore, vary widely on the two classes of river, nevertheless there is one definite connecting link, namely, that in both cases the river acts as a feeder to and distributor from ocean trade. This result is achieved in different ways according to navigational conditions, but it is a feature of the utmost importance. In short, modern types of river traffic, save as a corollary of sea-borne trade, do not exist anywhere in the world. This is a fact which will bear frequent repetition. The importance of this proposition may be judged from the Russian plan, under execution before the war, of linking up the White, Caspian, Azov and Black Seas by a continuous waterway capable of taking 10,000 ton ships as far as Moscow from the Black Sea and 10,000 ton barges carrying oil from the Upper Volga to Leningrad. This programme was to have been completed by 1946, but had to be suspended on account of the war. By August, 1945, however, work had been resumed on the Manych Waterway which will link the Caspian and Azov Seas.

It is also to be noted that where there are industrial areas along the banks of a river, the chances of developing river traffic involving transhipment are thereby enhanced. In fact, I incline to the belief that, without industrialisation, river transport involving transhipment at mouth in addition to transhipment upriver is not likely to make much headway. This is a possibility to be remembered.

CHAPTER II

NAVIGABLE RIVERS AND WATERWAYS OF THE GANGETIC SYSTEM

Few people realise the vast extent of the network of navigable rivers and waters in the three provinces of the United Provinces, Bihar and Bengal. In a large part of this area this navigation has a potential transport capacity far greater than the existing road and railway systems put together. The total mileage of channels permanently navigable for vessels of a minimum of 4 feet draft is, as near can be estimated, 1,728 miles, and of temporary channels (i.e., which such vessels can navigate in the rains only) at a further 472 miles.

In addition to the above, navigation of a minor sort is possible to smaller vessels over a much greater range. Many rivers, though small on the map, are navigable by small boats during the rains throughout almost their entire length, which, in some cases, extends for well over a hundred miles. Examples of these are the Gomti, the little Gandak and the upper Damodar, but there are many others.

In addition to the rivers, there are canal systems in each of the three provinces, which are, to a limited extent, capable of navigation. In general, however, as will be shown, canals built for the dual purpose of irrigation and navigation are unsatisfactory for the latter purpose for a variety of reasons, and it is doubtful if such canals have, except in special cases, much real utility in modern conditions of water transport.

In the table given below, I have attempted to compute the total mileage of waterways, navigable and non-navigable, in the U. P., Bihar and Bengal. The figures for Bihar and Bengal are based on an abstract from a statement of navigable rivers, *khals* and canals in the province of Bengal published in 1866, and quoted in Mr. Bramley's report on trade conditions and crime on navigable waterways in Bengal, Assam and the United Provinces 1904-1906. The remaining figures have been compiled by measurement on a map of scale 32″ to 1 mile—a method involving a good deal of labour and, I fear, indifferent accuracy. The U. P. figures for navigable rivers include only those likely to be able to connect with a transport service of modern type terminating at Bahramghat, which is the highest up-river such a service is likely to reach.

Province	Permanent (a)*	Permanent (b)**	Total	Temporary (rains only)	Total Cols. 3 & 4	Non-navigable	Grand total
1	2	2A	3	4	5	6	7
Bengal	1,008	5,740	6,748	5,043	11,791	3,990	15,781
Bihar	232	1,476	1,708	2,274	3,982	2,840	6,822
U. P.	488	384	872	250	1,122	6,206	7,328
Total	1,728	7,600	9,328	7,567	16,895	13,036	29,931

Col. (a)* includes only those waterways navigable to vessels of 4 draft throughout the year.

Col. (b)** includes rivers navigable to vessels of less than 4 ft. draft throughout the year.

The most important of all the rivers of the Gangetic plain is of course the Ganges itself. This great river rises in the State of Tehri-Garhwal, in 33° 55′ N. and 79° 7′ E. from an ice-cave near Gangotri, 13,800 feet above the level of the sea, and flows into the Bay of Bengal after a course of 1,557 miles. Up to the point where it receives the Alaknanda at Deoprayag, the river goes under the name of the Bhagirathi ; after this point it is called the Ganges. Starting as a stream only a few yards wide, it quickly adds to its size, and, at Hardwar (1,024 feet) it is already a fair-sized river with a discharge, in the dry season, estimated at 7,000 cubic feet per second.

Above Hardwar the river is used for floating down soft wood sleepers from the Garhwal forests. A few bamboo rafts may also be seen proceeding down stream, the river being too swift for up-stream traffic.

At Hardwar are the headworks of the upper Ganges Canal, on which navigation proper begins, and to which we shall refer later. Thereafter the diminished river flows on to Naraura, 143 miles from Hardwar, where still more water is drawn off for the lower Ganges Canal. 34 miles further on, the river is, to some extent, replenished by the waters of the Ramganga. At Allahabad occurs the confluence of the Ganges and Jumna, and it is from here onwards that the river has a special interest from the point of view of inland navigation.

From Allahabad to Digha Ghat the river skirts the districts and headquarters towns of Mirzapur, Benares, Ghazipur and Ballia. About 10 miles above Dinapur the Ganges is joined by the Gogra, its largest tributary during its whole length, and itself an important navigable river. At the same time the Ganges

receives on the south bank the Son, also a fair-sized river, though not navigable to power vessels. Though this range of the Ganges is navigable in the rains to fairly large craft, it is not always so in the dry season, except below Buxar, to vessels drawing four feet of water.

From Digha Ghat to the Nadia Rivers forms the next natural division of the river. Four or five miles east from Digha Ghat occurs the junction, from the north, of the Great Gandak River, which is, to a certain extent, navigable and could be made more so. Opposite the point of confluence is situated Patna, capital of Bihar province. From here to the point of offtake of the Bhagirathi, the most westerly of the three Nadia distributaries, the river flows in a solid stream, receiving no very important tributary except the notorious Kosi, which joins it shortly before it turns south past the Rajmahal hills. In this particular range, apart from Patna, the only place of any size on its banks is Monghyr, and, at a few miles distance, Bhagalpur. This entire range is navigable at all seasons by steamers drawing from 4 or 5 feet of water, and is the most stable from the navigational point of view.

The last stage of the river is from the Nadia Rivers to the sea. This stage is in many respects the most interesting of all, and is certainly the most important. It is from here that the delta of the Ganges begins.

Up to about 400 years ago the main stream of the Ganges. flowed down the channel of what is now the Bhagirathi and the Hooghly, entering the Bay of Bengal south east of Calcutta via what is still known as the Adi Ganga, part of the course of which followed the present Tolly's Nullah. About 300 years ago, whether by reason of specially violent floods, or some subterranean upheaval, the river burst through a clay belt which up to that time had arrested its eastward progress. In subsequent years the Jalangi and Matabhanga in turn became the main channel. The river's continued severe pressure on its eastern bank, however, caused it eventually to burst through in volume towards the Brahmaputra which it now joins at Goalundo, leaving the three Nadia distributaries functioning only as spill rivers in the rainy season.

The main Ganges stream over this range is navigable throughout its length by vessels drawing 5 feet or so. One drawback is that the Meghna estuary, through which the main stream enters the sea, is subject to a very strong bore. Another is the frequent change of main channel from year to year, so much so, that permanent steamer stations are in many cases an impossibility.

Apart from these defects the opportunities for navigation are good.

The Bhagirathi, the Jalangi and Matabhanga make up the Nadia rivers. The two former join at Nadia and from that point onwards their combined stream flows on to be eventually called the Hooghly. None of these rivers is navigable by large craft except in the rains, and even then navigation on the Matabhanga is risky for steamers. The Bhagirathi is the most used, and some effort and expense have been made to deepen it though with indifferent success. In the dry season the Bhagirathi is frequently totally unnavigable ; country boats can negotiate the Jalangi, but may have difficulty, while the Matabhanga is generally closed to traffic. Navigation between the Hooghly and the main Ganges stream via one or other of the Nadia rivers is therefore at all seasons more or less a matter of difficulty.

The Hooghly is navigable during the rains by all inland craft, but in the dry season between Nadia and Hooghly itself, a distance of 51 miles, it has insufficient depth for anything other than small boats. The river is tidal as far as Nadia and even 5 miles beyond. This tidal scour, and the fact that the Hooghly River is in a deep bed, [redacted] it to rely for 20% of its water supply on infiltration from other rivers and subsoil water, are the main reasons for its all-round-the-year navigability over the 115 miles between the town of that name and the sea.

During the 18th century a serious deterioration occurred in the upper reaches of the Hooghly owing to an alteration of the course of the Damodar, the principal tributary on its right hand bank. This river originally joined the Hooghly at Naya Sarai, 39 miles above Calcutta, and its waters assisted in scouring the Hooghly channel. In the eighteenth century a series of great floods burst the Damodar embankments and the river mouth moved further and further down the Hooghly till at last it reached its present position 70 miles to the southward of the old one. The old course of the Damodar rapidly silted up, and is now only a languid, muddy *khal.*

With the loss of the Damodar as a tributary of the Hooghly above Calcutta, the latter river began a process of silting up, to the ruination of the various settlements along its bank. The first to go was the Dutch settlement at Chinsurah, then in turn the French settlement of Chandernagore, the German at Bankipur and the Danish at Serampur. This silting process proceeded very gradually: in 1797 Admiral Watson took his fleet, including a ship of 64 guns, as high as Chandernagore for the bombardment of that town, and as late as 1821 ships of 800 tons went as high as

Serampur. After 1825 deterioration was more rapid, but until 1865 inland navigation was carried on by light draft steamers as high as Cossipore. On the construction of the East Indian Railway even this restricted navigation gradually ceased.

By 1853, fears that the deterioration of the Hooghly would eventually extend to Calcutta, had reached such a pitch that Lord Dalhousie in that year appointed a committee to enquire into the nature and progress of the river's deterioration. It was believed that at no distant date, ocean-going ships would no longer be able to approach Calcutta and a project was discussed to build a new port, 28 miles to the south-east on the Matla river. The evidence produced was sufficient to dispel the fear that Calcutta would cease to be a port, but the project to build the new port was later revived and carried out. Port Canning, as it was called, turned out a failure, and it appears quite certain that Calcutta will not easily be ousted as the principal port of Bengal.

The upper reaches of the Hooghly, however, are still deteriorating from the navigational point of view, and as this river will be a necessary link in any scheme of developed water transport between Calcutta and upcountry, this is a matter of serious concern. Improvement of the Bhagirathi may set up sufficient scour to maintain navigation in the Hooghly's upper reaches, but whether or not, the problem of restoring and maintaining deep water in this part of the river is paramount.

Near the mouth of the Hooghly, and just above the confluence of the Rupnarain with it occurs the greatest danger to navigation on this river. The combined waters of the Hooghly and Damodar are held up by those of the Rupnarain which cut straight across at right angles. The result is that much silt in suspension is dropped, causing sandbanks to form. These sandbanks are extremely unstable and subject to almost daily change. Vessels touching bottom on these sands are liable to be immediately overset and lost ; in most cases total loss is a matter of only a few minutes. In 1694 the vessel "Royal James and Mary" was lost on this shoal, and ever since then it has borne the name James and Mary sands. These sands are the main reason for the Hooghly Pilot Service, thanks to the careful work of which, wrecks nowadays scarcely ever occur.

Two more distributaries of the Ganges remain to be described. The first of these, the Ichamati, is an offshoot of the Matabhanga which it leaves at Kishanganj. It flows south-east through the Sunderbans into the Raimangal estuary. It is navi-

gable throughout by country boats at any season and by all inland craft as far up as Bangaon.

The last distributary is the Garai (also in its lower half called the Madhumati). This river is one of the principal distributaries of the Ganges and has a navigable course of 230 miles. Navigation is safe and easy on this river which terminates in a fine estuary, the Haringhata, 9 miles wide at mouth. Its main recommendation is that the estuary and river are unaffected by bore, and the river is navigable to opposite Morrelganj in Khulna district to ocean-going ships. The bar at the estuary entrance has 17 ft. minimum depth of water at low tide. The Garai carries much water in the rains when backing up of the Ganges waters occurs as a result of the higher water level in the Brahmaputra. The same phenomenon, however, causes it to silt up at its head. Subject to this it would be in every respect a suitable waterway for modern inland navigation, but unfortunately through navigation by steamers was prevented at the end of last century by the construction of a low level railway bridge near Kushtia at its head.

The annual rise of water in the Ganges during the rains varies somewhat. The greatest known is 45 ft. 6 inches at Allahabad, but this was an exceptional flood. Normally the rise is between 25 and 35 feet from Allahabad to the Nadia rivers. In the Nadia rivers it is between 20 and 25 feet and from there drops rapidly till at Calcutta it rarely exceeds 7 feet exclusive of the rise of tide.

A brief summary of the main tributaries of the Ganges from Allahabad to the sea will be of interest.

The first of these is the Jumna. This river though famous in history and formerly a useful waterway, is nowadays of no account as a navigable river. Though it has a longer course in the United Provinces than the Ganges it carries a much smaller volume of water, and its waters are actually insufficient for the irrigation canals which take off it, so that these have to be replenished from the Ganges Canal through what is called the Hindan cut. The river is, however, navigable during the rains as high as Agra. Formerly much money was spent clearing away kanker reefs and conglomerate in Etawah district, and before the opening of the E. I. Railway cotton grown in Bundelkhand was sent down river from Kalpi. At present the upper reaches of the river from the Himalayas to Abdullapur are used for floating timber cut from the forests of Chakrata and the Punjab Hill States. This timber is carried down by the Tons which at the point of confluence is the larger river. On the lower reaches of the river between Kalpi and Allahabad there was formerly trade in stone

and grain ; but there is practically nothing now except a few ferry boats.

The next tributary of the Ganges is the Gomti, with its tributary the Sai. The Gomti is navigable throughout the year from Muhamdi, a small town in Kheri district, though only for boats of light draft. Its course is generally tortuous, but its banks are throughout well defined and for minor navigation to boats drawing up to three feet or so, it could with little difficulty be kept open throughout the year from its mouth as far as Lucknow.

The fall of the Gomti at Lucknow is 9 inches per mile and at Jaunpur 6 inches. This sudden check is the cause of heavy flooding in the rains, the rise sometimes exceeding 20 or 25 feet.

The Son rises near the Narbada at Amarkantak in the Maikala range. Its early course is through hilly and rocky country, and it joins the Ganges 10 miles above Dinapore after a course of about 487 miles.

The Son is not navigable except in the rains, and even then it is dangerous owing to its excessive speed. In the hot weather navigation is impossible owing to the small depth of water.

The Son's main importance is as a source of water for the Son canals constructed between 1869 and 1875, and these will be referred to later in this chapter. An important tributary is the Rihand, the proposal to dam which will have a beneficial effect on navigation on the Ganges below Buxar.

The Gogra is by far the most important tributary of the Ganges from the navigational point of view. It rises in Tibet in 30° 4′ N. and 80° 48′ E. It flows through Nepal under the name Kauriala and enters the United Provinces between Kheri and Bahraich district. Shortly afterwards it is reinforced by the Girwa, the Suheli and the Dahawar, the latter two being branches of the Sarda. At Bahramghat occurs its confluence with yet another branch of the Sarda, the Chauka. From this point the river becomes navigable throughout the year for modern craft.

Between Bahramghat and its junction with the Ganges, a distance of about 300 miles, the river is in places unstable but there is always a deep channel left after every rains. The average fall is between 6 and 6½ inches per mile. The flood rise in the rains is moderate, being only 8 to 12 feet in normal years. The depth of water in the deep channel is sufficient at any time of the year to float vessels drawing 4 ft.

This river was in former times much used for navigation and until the opening of the Bengal and North Western Railway, trade on the river was of great importance. Even after the open-

ing of the railway steamers plied as far as Bahramghat and, for parts of the year, even beyond the Elgin Bridge up to a distance of 40 miles. River steamers used also to ply between Patna and Ajodhya, calling at many places and competing with the railway for both goods and passenger traffic.

There is still considerable traffic on the river, all carried in country boats, with the exception of the ferry steamers at Ajodhya and Dohrighat. That at Ajodhya plies in the rains only. At Bahramghat the Forest Department used to maintain saw mills for preparation of timber carried by river, but these were later sold. The chief traffic now is downstream only and consists almost entirely of boatloads of rice from Lakarmandi (the river port for Nawabganj in Gonda District) to Patna.

The Rapti, which flows through Gonda, Basti and Gorakhpur districts is a sluggish, winding stream carrying much silt, and is in consequence very unstable. Though small, it is capable of navigation to a certain extent particularly during the rains. It is liable to severe flooding, and has in the past caused much destruction to agriculture. Navigation in this river is now practically non-existent.

The Great Gandak is a very considerable river which takes its rise in the snows of Nepal and enters the plains through a gorge near Tribeni Ghat, about ten miles north of the U. P. frontier. Even in the hot weather the volume of the Gandak is immense, the minimum discharge being about 10,300 cusecs, much more than that of the Ganges at Hardwar. It is navigable for small boats up to 20 or 25 miles above the Tribeni gorge, though navigation is difficult by reason of eddies and whirlpools. Shortly after entering the U.P., the Gandak acquires the character of a deltaic river, its banks being above the level of the surrounding country, which is protected by artificial embankments from inundation. In spite of these the Gandak frequently does overflow its banks causing very severe floods in the Champaran, Saran and Muzaffarpur districts. This river is navigable throughout the year for vessels of moderate draught for a distance of 170 miles or so between Bagaha in the Champaran district of Bihar and its confluence with the Ganges opposite Patna. Modern vessels of 4 feet draft could navigate it at any season of the year as far as Lalganj about 25 miles from its mouth. I have been unable to find particulars of the fall of this river, but it may be assumed to be well within the limit of 10 inches per mile. One feature of note about this river is that its bed has been raised so high above the surrounding country that it has, in its lower half, no tributaries—

in fact, the drainage of the neighbouring country sets, not towards it, but away from it.

The Great Gandak was formerly very largely used for the carriage of goods, and a register kept for 4 months in 1868 showed an export of over 8 lakhs maunds. This river, in its lower reaches at least, has distinct possibilities for development as an inland waterway.

From the confluence of the Great Gandak with the Ganges at Patna no considerable tributary exists till the Kosi is reached. The Kosi rises beyond Nepal and by the time it enters Bhagalpur district it is a large river nearly a mile wide, and has assumed the character of a deltaic stream. Its total length between that point and where it meets the Ganges is 82 miles, and these 82 miles are among the most destructive in all the Gangetic system. The river is constantly shifting in a wide pendulum arc and leaves behind a mass of sand in which nothing can be cultivated, and only grass can grow. The current is too swift for satisfactory navigation. Sandbanks and channels are continually shifting at all seasons of the year and the channel is frequently rendered dangerous by sunken trees. The Kosi has never been much used for navigation by reason of these features and it does not seem likely that it ever will.

The Mahananda is the last of the large tributaries on the left bank of the Ganges. This river is navigable all the year round by vessels of 3 feet draught as far as Ramassarai and Malda about 50 miles upstream from its junction with the Ganges. In its upper reaches it is too rapid for satisfactory navigation.

The Damodar has already been referred to. This river is navigable throughout the year by vessels of moderate draught, and as far as Amta by steamers, but on spring tides only. This river rises in the hills of Chhota Nagpur and after a course of 368 miles falls into the Hooghly about 35 miles south of Calcutta. The river is affected by the tide as far as Raspur, 2 miles above Amta. At Amta the spring tide rises 2½ feet in summer, while at Manishreka, ten miles further down, the rise at neaps and springs is 5 and 8 feet respectively. From March to May, the river is subject to bores, with a wave that seldom exceeds 4 feet, varying according to weather and tide. The least depth of water at Manishreka is 6 feet in summer. Above Amta the river shrinks to a very small stream in the hot weather.

The river is full of sandbanks, and the fall below Amta is 3½ feet per mile—much greater than is desirable for navigation, so that the speed of the current interferes with navigation in the

rains. Many attempts were made at the end of the last century to restrain the river from flooding by means of embankments on both sides of the river, but these, especially that on the south side, were continually swept away and in the end the attempt to maintain an embankment on the south side was abandoned.

Near the Damodar mouth, the Rupnarain joins the Hooghly. The Rupnarain, as we have already seen, is the main cause of the formation of the James and Mary sands, the chief danger to navigation in the Hooghly. It is navigable throughout the year as far as Banda, 46 miles upstream, on the flood tide only, by vessels of 4 ft. draught. It is tidal as far as Silai. The river is subject to heavy bore during the hot weather. Both banks are protected by artificial embankments.

A description of the Gangetic rivers cannot be complete without some account of the Sunderbans. This area consists of the lower part of the Ganges delta and is intersected from north to south by the estuaries of that river. The whole area is one vast alluvial plain covered with jungle and swamp. The distributaries of the Ganges are here linked up by an intricate series of branches and by inumerable channels so that the whole tract is a tangled network of streams, rivers, watercourses and artificial canals, the navigable length of which amounts to 1,127 miles, of which only 47 miles are artificial and the remainder natural channels. These channels run generally in an east-west direction between the Hooghly and the Meghna estuary. The inland channels are constantly shifting as the deposit of silt raises their beds and the problem has always been to keep the natural channels clear of silt and to connect them with each other and with Calcutta by a system of artificial canals.

The objective of this system is Barisal, the headquarters of the rice-growing district of Backergange situated 187 miles to the east of Calcutta. There are three alternative routes—the first two being the Inner Boat route and the Outer Boat route. A branch of the latter is the steamer route which follows a more exposed channel for the first part of the journey from the Hooghly. At the eastern end of the system is the Madaripur Bhil route which joins the Kumar and Madhumati rivers and is used by jute-steamers in the rains.

The Inner Boat route is navigable at all seasons by vessels drawing up to 6 feet but some points must be passed on the flood tide. The Outer Boat route is navigable by vessels drawing 8 feet but much trouble has been experienced by the silting up of Tolly's Nullah which connects this route with Calcutta. The

steamer route has considerably greater depth but is exposed to bad weather.

As previously mentioned in connection with the Nadia rivers, all the Ganges Delta is tidal. The sea water, being of greater density, flows north on the flood under the fresh water current of the river. On the surface, therefore, there is always a south-running current, but at a certain depth the northward flood-tide can be found. The influence of the tide is felt as high up as Nadia, especially during the dry season. The greatest mean rise of tide, about 16 feet, takes place in the months of March, April and May, and declines to about 10 feet in the rains, with a minimum during freshes of 3 feet six inches.

The incoming tide running up the narrowing estuaries of the delta produces a bore, or tidal wave, often exceeding 7 feet in height, which travels at a speed from 10 to 15 miles an hour. This bore is not necessarily dangerous provided boats meet it in mid-stream, but those caught without way near the shore are apt to be carried on to the bank and wrecked.

Power craft properly handled need never come to grief provided elementary precautions are taken. The strength of the bore varies according to the shape of the estuary and distance up river. It is strong both on the Meghna and the Hooghly. It is nevertheless not normally a matter of concern for inland navigation. Certain estuaries, notably the Haringhata, are freer from bore than others.

The above concludes a brief sketch of the natural waterways of the Gangetic plain. There still remains the subject of navigation on canals linked to the Gangetic rivers. There are several of these, and, apart from the Sundarbans canals, which have been already mentioned, and the Hijili and Orissa coast canals, they were constructed to serve the double purpose of irrigation and navigation.

The first of these are the upper and lower Ganges canals. The first named takes off from the Ganges at Hardwar. From there it proceeds through Roorkee southwards through the Meerut Division. At mile 22 it throws off the Deoband branch, at mile 50 the Fategarh branch and at mile 181, at Nanu in the Aligarh district, it splits into the Cawnpore and Etawah branches. The lower Ganges canal crosses these branches in their 32nd and 39th mile respectively, and from these junctions they are considered to be a part of the latter canal system.

The upper Ganges has a main line of 213 miles and all of it provides navigation for boats drawing 5 feet when running full

supply. Navigation used to be continuous from Hardwar to Cawnpore but lately various regulators have been added over which barges cannot pass, and continuous navigation beyond mile 87½ is no longer possible. The minimum width of the canal is 200 feet. Locks are 108 feet long and 16 feet wide.

The lower Ganges takes off at Naraura. At mile 25 the Fatehgarh branch is given off, and at mile 40 the Besar branch. At mile 55 the main canal meets the Cawnpore branch of the upper Ganges. The main channel terminates in the Cawnpore district.

The main channel of 62 miles and 137 miles of branches are navigable by boats of draft and dimensions similar to those on the upper Ganges.

As already remarked, both these canals were constructed for the double purpose of irrigation and navigation. In fact, the Court of Directors of the East India Company appear to have had some difficulty making up their minds as to which purpose was the more important, for in 1844 they informed Mr. Thomason, Lieutenant Governor of the North West Provinces, that the main object of the upper Ganges canal was to be navigation and not irrigation. Eventually, the claims of irrigation won, but navigation was retained as an important sideline.

In spite of the elaborate provision for navigation on these canals, operations have always been carried on at a loss, and tolls have never amounted to more than half the navigational expenses. Recently, as above hinted, the policy of keeping the canals open to navigation has practically been abandoned.

The next series of navigable canals to be encountered on the Ganges are the three main canals of the Son system which take off from Dehri and have an aggregate length of 218 miles. These canals fall into the Ganges at Buxar, Arrah and Dinapore respectively. The traffic has always been moderate and the tolls have never met the expenses due to navigation. The opening of the Moghalsarai-Gaya railway caused a serious diminution in the traffic, receipts dropping suddenly to about a quarter of the average of the previous years.

The Midnapur high-level canal, constructed between 1866 and 1871, is a combined irrigation and navigation canal connecting Midnapur with Ulubaria on the Hooghly, a total length of 72 miles. This canal derives its water supply from the Kasai river at Midnapur, and during its course it crosses both the Rupnarain and Damodar rivers.

The maximum discharge of this canal is 1,500 cubic feet per second. It is navigable throughout its entire length, and steamers

can negotiate it at certain seasons. The estimated value of goods carried in 1902-03 was nearly Rs. 64 lakhs, on which tolls of Rs. 70,000 were collected. Before the opening of the Bengal-Nagpur Railway the canal formed part of the main route between Calcutta and Midnapur: the railway caused a distinct falling off in receipts from navigation.

This canal, if improved, extended to Tatanagar, and maintained as a power-vessel route throughout the year, will be one of the most important links in a modern system of transport on the Gangetic rivers. Further mention will be made of this in Chapter 6.

At the mouth of the Rupnarain there take off the Hijili and Orissa Coast canals, both of which are navigation canals pure and simple. These latter connect the Hooghly with the Orissa canals radiating from the Mahanadi River at Cuttack. The construction of the Hijili and Orissa coast canals did not result in the increase of traffic anticipated. The gross receipts of the three canals were less than Rs. 1,40,000 in 1902-3 and of this Rs. 23,000 only was net revenue although the expenditure on navigation alone was estimated at a crore of rupees. The construction of the Bengal-Nagpur Railway effectively destroyed any hopes of its improvement in the future.

None of these canals therefore has been an unqualified success from the navigational point of view ; nevertheless it would be unjust to condemn those responsible for introducing navigational facilities into their construction. All of them were built or at least projected long before the railway across India had been completed, and all of them were in operation before the railway had affected their local areas. Road traffic at that time was inadequate to cope with the movement of bulk supplies and a navigation canal or even an irrigation canal with navigation as a sideline was a great help towards the solution of certain forms of transport. We shall see in the next chapter how even the smallest rivers were utilised to the utmost in the past for transport of bulk cargoes and how subsequently the river traffic in those cases was unable to compete with the railways. But in the case of irrigation-cum-navigation canals there are certain serious disadvantages. A canal which has irrigation as its main object is designed to traverse rural areas and to avoid large towns, whereas a purely navigational canal seeks to include as many industrial towns as possible in its course. Secondly, from the engineering point of view it is desirable that an irrigation canal should have a distinct fall in level as it proceeds. It is therefore designed to travel at right angles, more or less, to the contour lines

of the country. Excessive rate of flow is avoided by the insertion of numerous falls and weirs, so that the water runs down a gigantic series of shallow steps and stairs. All this is undesirable from a navigational point of view. A purely navigational canal will seek to follow the same level throughout, in order to avoid current and will therefore run as far as possible along the contour lines. Falls entail locks, which mean extra labour, expense and delay. Another drawback is the destructive scour set up by the wash of power-operated vessels. Irrigation canals are not masonry lined nor are their banks constructed with the necessary slope to bear this wash, and it would be a most expensive business to make them so. Lastly irrigation canals are liable to considerable fluctuations in water depth depending on irrigation programmes, and are frequently emptied of water altogether for days and sometimes weeks on end. This, from the point of view of transport, is the worst defect of all. Irregularity of trade flow, as we have seen, is one of the most undesirable features in any transport system, and particularly in a water transport system which must of necessity be much slower than the railways. The conclusion is necessarily reached that except in special circumstances a canal cannot adequately serve a double purpose, and it is significant that in the case of the Jumna and later canals the policy of providing for navigation as a sideline was definitely abandoned.

In conclusion the existing possibilities of navigation on the Gangetic rivers may be summarised. Starting from Calcutta, there is adequate depth of water for vessels proceeding up-country at all seasons provided they proceed via the Sunderbans to the main Ganges stream, thence westwards up the Ganges as far as Buxar on the Ganges and Bahramghat on the Gogra. Side-routes as far as Malda and Nemassarai on the Mahananda and Lalganj at least on the Great Gandak are also distinctly possible.

The main obstacle to communication between Calcutta and upcountry ports is the lack of water in the upper Hooghly and Nadia rivers during the dry seasons. At present it can be avoided by the Sunderbans detour but the alternative route means an extra 400 miles—a very serious drawback indeed. If a channel in the Bhagirathi cannot be kept dredged out sufficiently to allow it to be used throughout the year a navigation canal might be the alternative solution but this is a matter for decision after a thorough survey of the position. If however there is a sufficient justification for a revival of river traffic between Calcutta port and upcountry there is no doubt whatever that a permanently navigable water channel either in or parallel to the Nadia rivers is a *sine qua non.*

CHAPTER III

HISTORY AND REASONS FOR DECLINE OF GANGETIC NAVIGATION

In the past, up to the advent of the Grand Trunk Road and the railways, the rivers of the Gangetic plain were extensively used for commercial navigation. The Ganges and Jumna were early recognised as the main highways for travel and trade along their entire range from the Punjab border to Eastern Bengal. The extent of the development of this navigation prior to 1750 is not known ; it was however in all probability restricted to comparatively short river ranges. There is more than one reason why this should be so. In the first place, in spite of the extent of the dominion of various great dynasties from time to time, law and order was always locally a matter of speculation, and boatmen and merchants would be chary of navigating in areas where they were not certain of protection from the local administration against robbery and piracy ; secondly, navigation was fraught with difficulty on account of sandbanks and other changeable features of the river. Local knowledge was necessary, but this could not be relied upon to extend beyond a comparatively short stretch of the river.

In the comparatively infrequent use of the rivers by the armies of the Moguls, I see evidence of the above conditions. The only occasion which I can trace of the use of the Ganges to transport an army was when Akbar, for his conquest of Bengal in 1574, voyaged down the rivers and drove Prince Daud from Patna and Hajpur at the height of the rainy season. It is certain that had long distance traffic been developed to any extent on the Gangetic rivers, much more use of them would have been made at this period for the purpose of transport of armed forces and carriage of military supplies.

It is not till we come to the 17th century and witness the increasing influence and dominion of the East India Company that we see the river really begin to develop as a long distance commercial highway. Two factors contributed to this : the first, increasing growth of an export trade from Calcutta ; the second, establishment of law and order in the territories administered by the Company. Both these factors were of equal importance. It must not be inferred that these conditions were speedily realised : even in the time of Warren Hastings there were many complaints of inter-

ference by local Rajas in Oudh with boats using the rivers. Conditions however had so much improved by the end of the eighteenth century that there began about that time an era of great prosperity for the rivers, which were at this time the sole means of conveying to Calcutta the foodgrains and other produce of the Gangetic plain. The trade was not confined to the produce of the riverain tracts only, but extended in some cases to areas far removed from the rivers, even where this entailed considerable carriage by road followed by transhipment. The main example is probably that of the cotton of Central India which was brought to Kalpi on the Jumna, and from there shipped to Calcutta.

The East India Company, as was to be expected, paid considerable attention to the improvement of the conditions of navigation on the Gangetic rivers. A survey of the river was undertaken by Rennell, Surveyor-General, in 1764-65. This survey did not include the Ganges-Jumna Doab from Allahabad upwards, which was first carried out by Charles Reynolds in 1793, the occasion being the threat to the safety of the Company's provinces from the restless Zaman Shah of Kabul, son of the famous Timur. The East India Company required information of the geography of the country as a preliminary to planning a defensive military campaign. Further surveys took place between 1793 and 1797 when Zaman Shah invaded the Punjab and threatened Delhi.

The next two surveys of the Ganges were made by Colebrook, Rennell's successor. The first of these, made in 1801 included the Ganges as far as Allahabad ; the second made in 1807, extended up to Cawnpore. In 1828 Captain Thomas Prinsep made an investigation into the suitability of the Ganges for steam navigation, using for the purpose Colebrook's maps brought up to date. His report was favourable, and in the time of Lord William Bentinck in 1834, steam traffic was greatly developed and a regular line of steamers worked between Allahabad and Calcutta. English coal was then about Rs. 20/- per ton in India, but about this time Indian coal was discovered in Bengal. This coal, though inferior, was 25% cheaper delivered on board, and rapidly superseded English coal. The first steamers were sternwheelers about 120 feet long by 22 feet beam, with engines of 40 to 90 nominal horsepower, giving a speed of 6 to 7 m.p.h. In the rains, when the Bhagirathi was open, they took 20 days between Calcutta and Allahabad and 8 days on the return journey. In the dry season they navigated via the Sunderbans, the up journey taking 24 days and the down journey 15. Cabin passengers were charged £30 sterling (Rs. 400/-) for the whole distance, and the rate for goods was £6

per ton of 40 cubic feet (approximately Rs. 3/- per maund), but the rate bid at auction sometimes reached £20 a ton, or a little less than Rs. 10/- per maund.

In those days the same steamer never conveyed both passengers and goods. Passengers were taken in a barge termed an "accommodation boat", which was towed behind the steamer. Goods were carried in the same way in a freight boat or flat, the steamer and her tow being linked to each other at bow and stern by flat beams which acted both as struts and as means of communication.

Until 1844, the East India Company enjoyed a monopoly of steam navigation on the Ganges, but in that and the following year two independent companies were formed for establishing and running a line of iron steamers between Calcutta, Mirzapur and Allahabad. Mr. Albert Robinson after studying navigation on the Mississippi, and the peculiarities of the Ganges, built in 1844-47, on behalf of the Ganges Navigation Company, five steamers to run single-handed between Calcutta and Allahabad. This was an important departure from the system of towing accommodation boats or cargo flats. The Patna, one of these steamers, which was constructed in Millwall, and put together in Calcutta, made her first voyage to Mirzapur in September 1846, and the Press of the day had notices of her "rapid" passage made in 11½ days. The new departure however did not meet with the success it deserved, owing to losses incurred through lack of proper pilotage. The Ganges Company received its final blow in a violent cyclone which occurred in 1864, and was shortly afterwards absorbed by the India General Steam Navigation Company. Running steamers single-handed was not again adopted, except for ferrying, until the Assam Mail Service was started in 1883.

Steam navigation, nevertheless, rapidly throve, and extended over a most remarkable range of the river. In Thornton's Gazetteer of 1854, it is stated that steamers conveying passengers and treasure ply as far as Garhmuktesar, in Meerut District, 393 miles above Allahabad ; and as far as Cawnpore, 140 miles above Allahabad, navigation was "plied with much activity, the reach of the river at that military station having the appearance of a port on a small scale."

But even so, steam navigation never amounted to more than a comparatively small part of the total navigation on the river. The great bulk of the traffic was carried in country boats and these extended their navigation over the entire Gangetic range, from Delhi and the Nepal border up to Assam. The number of these

boats rapidly mounted till they could be counted in lakhs. There was scarcely a stream which could be navigated in the rains which did not become an important highway of traffic, and the East India Company's bold policy of deepening and improving rivers, and maintaining tow-paths helped not a little towards this remarkable development.

The first indication of a break in this state of affairs came with the construction of the Grand Trunk Road Between 1839 and 1842. This road however did not, in general, cause any considerable diminution of traffic on the river, though it did undoubtedly affect it to some extent. Major Abbott in 1844, reporting on the state of this road, while referring to the enormous increase in the number of travellers on it, states that many of them feared to use the metalled portion, imagining it to be reserved for the 'Sahib log'. This, and the large number of road dacoities, had a retarding effect on its popularity.

The construction of the railways between 1855 and 1870 did not immediately spell the doom of the river traffic. According to the Imperial Gazetteer, the opening of a trunk line acted rather as a stimulus to river traffic as a feeder to the railway in addition to the existing trade ; and traffic in oil-seeds, rice and other bulk goods actually increased up to the time when the construction of branch lines deprived the rivers of their role as feeders to the main line stations. For a time passengers steamers on the Ganges even competed with the railways for passenger as well as goods traffic.

The volume of the upward and downward trade of the interior with Calcutta alone by the Gangetic channels was in 1881 valued at about Rs. 27 crores. At Bamanghata, east of Calcutta 1,78,627 cargo boats were registered in 1876-77 ; at Hooghli 1,24,357 and at Patna 61,571. These figures, large as they are, represent only a fraction of the total number of boats on all the rivers of the Gangetic plain.

These figures cannot have been far off those of the peak years of river traffic. The figures of subsequent years show a considerable decline. The decline, as was to be expected, showed itself first in the upper reaches of the Ganges, where, owing to the lack of water depth, accentuated by the construction, between 1825 and 1854, of the Jumna and Ganges canals, navigation was the most difficult ; and where, on considerable stretches, it was entirely closed for 4 months in the hot weather. The decline was at first gradual, but between 1880 and 1890 it began to accelerate, finally culminating in a catastrophic and dramatic crash. As evidence of this, the Administration Report of the U. P. for 1886-87 states the

traffic figures by the Gogra-Ganges river to Bengal as 53,25,467 maunds, made up of 46,88,515 maunds exports and 6,36,952 maunds imports. The bulk of the exports was composed of wheat and other grains, and oilseeds ; the remainder being sugar, while upstream salt was the principal commodity, followed by tobacco and iron. The same report for 1888-89 gives the total figure of traffic with Bengal by the Ganges-Gogra as 48,16,400 maunds only of which 38,86,885 maunds represent exports, and 9,29,515 maunds imports, the nature of the commodities being the same. The drop in quantity over these two years is very considerable.

Evidence of the increased rate of decline is shown by the figures of cargo boats for the year 1905. An enquiry in that year showed the total number of cargo boats on the Gangetic rivers as 15,194 only, compared with those for Assam at 47,847. Incidentally, the total cargo capacity of these boats is stated as well over 120 crore maunds (nearly half a million tons) and as most of them did at least two journeys in a year, the actual cargo annually carried was considered to be at least twice these figures. In spite of the drop in the number of boats therefore, the extent of river trade was still considerable.

By 1907 the accelerated speed of the decline in traffic was further evident. The Benares District Gazetteer of that year says :

"The chief navigable river is the Ganges, and this stream still bears very considerable traffic, though its importance has been greatly diminished by the construction of railways . . . In 1897 the India General Steam Navigation Company extended the steamer service from Patna to Benares, but the venture did not prove profitable and was abandoned after a few years. The Gumti is navigable throughout the year by boats of a hundred maunds burthen, but the river-borne traffic on this stream has almost disappeared. During the rains boats of considerable tonnage might pass along the Barna . . . but the river is seldom utilised . . . . The decline of the river traffic was first observed about 1848, when the growing use of the Grand Trunk Road became a subject for comment. Hitherto the Ganges had been the main artery of commerce. In 1813 it was recorded that most of the grain imported into Benares came by that route, and again in 1828 mention is made of the large fleet of cargo vessels to be found in Benares, where alone it was possible to secure the boats required for 'Government investments.' "

The extent of navigation nevertheless then still carried on is shown from the Gazetteer of Mirzapur District of the same year. There the writer states that the Ganges is practicable for boats

of one thousand maunds burthen or even more during the rains, and enumerates 48 wharves on the south side of the river, and 31 on the north bank. He then goes on to give this remarkable information.

"It is the custom for the Mallahs, who form generally the class of boatmen and reside in the riverine villages, to leave the district after the Kajli fair in August. If their boats are large they take on cargoes of stone and grain, if they are small they carry passengers, the destinations being Sheorajganj, Dacca, Dulheri, Goalpura and even distant Assam. During the whole of the cold weather and up till the month of April they work as boatmen or pilots in the timber carrying trade of the Bengal rivers ; and then if the season is favourable and they have earned sufficient profits they sail homewards on the east wind with cargoes of rice, coconuts and similar things arriving in June or July. In good years as many as six hundred boats will return ; but if trade is bad and earnings have been low, only half this number may come home, the remainder staying on for another season's work."

The main decline as stated above, took place on the Ganges, but the upper reaches of the Gogra also felt the influence of the railways. As far back as 1903 it was recorded in the Bahraich District Gazetteer that,

"The river traffic of the district is still of considerable importance, although it has been very greatly affected by the development of the railway system. The Ghagra, Rapti and Sarju are all navigable. On the two former boats run up to 1,200 maunds, and on the latter during the rains large barges go up to Khairi bazar and thence carry grain. The smaller boats used will carry about three tons and draw two feet of water when loaded . . . . The trade is almost wholly in grain and timber, and very little now goes beyond Bahramghat, although at one time there was a considerable traffic in sugar with Azamgarh. Large quantities of sal logs are floated down the Rapti in similar fashion. Where, however, the forests are tapped by the railway, the river traffic has been almost entirely supplanted by the railway, which affords a means of transit that is not only more expeditious, but cheaper."

In every riverine district it is the same story—that the river traffic was formerly considerable, but the railways eventually took away all the trade ; even the rafting of logs no longer paid. There is now very little, if any, long distance traffic from Bahraich district down stream, and to make it even more difficult, the pontoon bridge at Ajodhya forms a barrier to navigation for seven or eight months of the year.

By 1913-14 the river traffic between the U. P. and Bengal had shrunk to very small dimensions. Not only so, but the trade flow had been reversed, so that imports greatly exceeded exports. The figures for that year were 2,07,669 and 45,016 maunds respectively, the principal import cargo being no longer salt, but cotton piecegoods. But even this trade diminished, and with the exception of 1918-19, when there was a brief revival, it sank steadily until in 1921-22 it was 83,196 and 26,893 maunds imports and exports respectively. This is the last year for which figures are available.

So far as I know, no analysis has yet been made of the reasons why the railways were able to compete with river traffic so successfully. It is frequently assumed that railways afford a cheaper system of transport particularly over short stages of haul. This may be so, but the proposition is at least open to doubt. It is certain that a locomotive and train of wagons cost not less to construct and maintain than a barge or barges of similar total capacity ; wharves and sheds cost no more than stations and sidings, buoyage and pilotage than a railway signalling system, and the organisational costs, including staff, will be at least no more for a navigation system than for those on the railway. This practically completes the list of major expenses in water transport, and as yet we have made no mention of the very considerable initial and maintenance cost of the railway track including embankments, cuttings, tunnels and bridges, for which, on the river transport side, apart from conservancy operations in certain areas we have no parallel. So far no railway company has ever considered as a practical proposition putting the comparatively short sea route between Bombay and Karachi out of business. Even now there is a considerable volume of passenger, grain, jute and other traffic in steamers and country boats up and down limited ranges of the Gogra-Ganges river. These facts require explanation.

In any transport system there are two sides—the engineering or constructional side, and the organisational side. Though no authority can be claimed for the opinion unless and until there has been a complete survey of comparative costs, I am definitely inclined to the belief that river transport in India, on the purely engineering or technical side can be made a much cheaper proposition than the corresponding aspect of railway transport. I firmly believe that the main reason why railway transport killed river traffic was not because it was a cheaper technical proposition. It was cheaper only because the comparative security and the complete and detailed organisation of the railway made it so. By

reason of this organization, the railway could cater for a multitude of classes of traffic which was entirely beyond the scope of the existing water traffic. Not the least important factor was that the railway had a complete monopoly of transport in its own area ; on the river there was a chaos of petty competition. So much is this so, that I believe that even if it were shown that railway transport, taken as a whole, was considerably dearer than river transport, its superior organisation would still eventually have driven the latter out of business.

But apart from this, it is very much open to doubt whether much of the river traffic of the 19th century ever was, *per se*, a satisfactory mode of transport. The great majority of the Ganges tributaries are navigable only in the rains ; in consequence the maximum number of journeys made by country boats doing the direct trip from upcountry from the U. P. and Bihar to Calcutta was not more than two per annum, and in most cases one only. But many rivers on their upper reaches could not float big boats even in the rains. This means that goods had to be conveyed to the ghat either by small boat, or by bullock cart : in either case the process entailed transhipment and in the case of bullock carts, considerable extra expense.

Further, the great bulk of the traffic was in grain or cotton. The worst time of the year to transport either of these commodities is in the rains, yet for vast areas, it was this time of year or nothing. The country boat has either no deck, or at most, a rudimentary one, so that the cargo was liable to be thoroughly soaked by rain water as well as by the river water which percolated freely through the loosely built hull.

The country boat is emphatically not an economical cargo carrier. Its loose construction and lack of longitudinal bracing are compensated for by high topsides. The lack of deck has to be compensated for by cross-bracing half way up the sides, which greatly interferes with stowage. Partly on this account and partly on account of leakage the cargo has to be piled up high, making the boat top heavy and losing cargo space where it is most valuable —low down in the boat. The lack of longitudinal strength and the high centre of gravity make the boat extremely vulnerable, particularly when loaded, in case of running aground on a narrow reef or sandbank.

Another reason against country boats is the uncertainty of their travel. On the large rivers they can often sail, upstream as well as down. On the smaller rivers they are poled down and towed upstream. Towing on the larger rivers also takes place when the

wind fails, but it is not always possible, as, for example, when a large tributary crosses the towpath. In such circumstances, there is frequently nothing for it but to wait for a favourable wind.

Lastly, comes what is really the main objection—that country boats cannot carry sufficient bulk of cargo. The number of boats and men employed per thousand maunds of cargo is at much too high a ratio. Apart from loading and unloading, a crew of 3 or 4 men is required for even a moderate sized boat carrying 500 to 1000 maunds downstream and 7 or 8 for a similar cargo proceeding upstream. By comparison a modern barge on European rivers taking 3,000 tons (50,000 maunds) is manned by a crew of only 2 or 3 men.

The main factors in transport as we have seen are bulk and speed. The country boat is suited for neither. In fact, it would not be too much to say that even before the days of railway competition, the capacity of all the country boats it was possible to build and the manpower available to man them was insufficient to handle anything like the total potential trade in riverine areas. This should provide a sobering reflection for those who consider that a revival of country boat traffic on a large scale is either possible or desirable.

It is further important to note that the organisation of river traffic—if organisation it could be called—had no machinery for onward transhipment or delivery. Not every destination is at or near the river bank : in fact, with the exception of Patna and Benares, there is no large city between Calcutta and North India to carry the trade of which navigation could be relied upon at all seasons of the year. The railway provided the reliable means of transport required and the result was a gravitational change of commercial centres from the river bank to the railway lines. Transhipment facilities from the river, which were now more than ever a vital necessity, were absent. Still further, the railways made possible traffic in small consignments of miscellaneous goods—a sort of traffic which was quite outside of the scope and capacity of country boatmen, who never, as we shall see, dealt in less than a boatload at a time. In the absence of onward delivery arrangements for such small consignments, the boatmen could not hope for a moment to compete in this class of traffic even if they had ever contemplated starting it.

Lastly one more highly important factor tended to the utter disintegration of river traffic in country boats. The rapid decline at the beginning of the century threw thousands of river boatmen

out of employment. Having been born and brought up as boatmen, they had little inclination and in many cases insufficient land, to turn to cultivation as an alternative source of livelihood. The result was poverty and desperation ; and inevitably a rise in crime. Freights were hard to come by, and the temptation to dispose of a valuable cargo when it did come, was in many cases too great to be resisted. The rapid rise of crime on the river was the subject of increasing complaint on the part of the merchants, and in this connection it is well worth quoting almost in full a letter from B. Sita Nath Roy, Honorary Secretary, Bengal National Chamber of Commerce, to the Chief Secretary to the Government of Bengal, dated 4th March 1892. The letter is also of the highest interest as showing the method of engaging boats, and its attendant risks and difficulties.

"At the outset," he writes, "my committee deem it necessary to state . . . . that the mahajans have no cargo boats of their own, and that whenever they have to dispatch goods they look to the boatmen for such a purpose."

"In fact, the boatmen and the mahajans are two entirely different parties, very often being utter strangers to each other and having no relationship with each other, except that the former lend their boats on hire to the latter at a certain rate per hundred maunds.

"Cargo boats are, as a rule, owned by the lower classes of Hindus and Muhammadans, most of whom are unscrupulous and do not hestitate to abstract as much of mahajans' goods entrusted to them as they safely can . . . .

"The practice now followed in hiring cargo boats is that the head manji has to be brought by the ghat manji (a sort of broker and negotiator between the boatmen and the merchants) before the mahajan, and he is at once engaged contingent, of course, on the settlement of the rates of hire per one hundred maunds. No question is then asked as to who and what he is, and no enquiry is made as to what sort of character he bears, but even if attempts were made to ascertain all these particulars nothing further is known, except what might be had from the lips of the head manji himself, for the majority of these boatmen never stick to their own villages but go to such centres of trade and commerce whether far or near where they believe they will find ready engagements for their boats.

"The next step after a boat has been engaged and goods loaded into it after weighment in the presence of the manji, is for the mahajan to note down in a khatta book the names of the head

manji and his father, and also the names of his native village and the police-station to which it is subordinate.

"Where a manji is honest and means no mischief or wholesale loot of the contents of the boat, on the way to the place of destination, he gives a faithful description of himself, but where a manji is dishonest and harbours wicked intentions, he is sure to give a fictitious description of names and places.

"Having successfully imposed upon the mahajan in the manner indicated above and contemplating mischief from the outset, the head manji, with the crew, weighs anchor and sets out on his journey, but very often instead of going by the right route he purposely deviates from it and looks out for the first favourable opportunity to dispose of the goods entrusted to his care and thus misappropriate the sale proceeds . . . . The ill-gotten booty thus disposed of, the boatmen set out on their way home. In the meantime, the consignee waits patiently week after week and even month after month hoping against hope for the safe arrival of the goods, but it is not long before that false hope vanishes and he sinks in blank despair, no goods are received and even no clue can be had of the missing boat or of its manji. He starts on enquiry and sends information to the police, but to no avail, for no manji or village of the name given to the consignor can anywhere be traced. The whole thing turns out to be mythical. Sometimes the dodge resorted to by the boatman in order to allay all suspicion of foul play is that after disposing of the whole or a portion of the goods he purposely wrecks his own boat (which very often is an old worthless one) then he circulates the story in the neighbourhood that his boat . . . . was caught in a storm or met with a serious accident and had done down, the same information being also furnished to the mahajan by a postcard.

"Apart from such cases of wholesale robbery, partial misappropriation of the goods by the manji are events of daily occurrence."

The letter concludes with a request that Government adopt certain measures recommended by the Chamber for the registration of boats and the licencing of crews.

One of the strongest factors in the ultimate decline of river transport undoubtedly was the prevalence of crime on the rivers and the inability of Government to take effective measures to stamp it out. Piracy, dacoity and even murder were rampant. In 1905 Mr. Bramley, District Superintendent of Police, Benares, was appointed to make an investigation into crime on the rivers in the provinces of the U. P., and Bengal (including what is now Bihar).

His report makes startling reading. According to him large organised gangs of dacoits and pirates operated over the whole Gangetic system from Fyzabad and Allahabad down to the Gangetic delta east of Calcutta. "It was clear," says the report, "that crime of a very serious nature was rampant on all the waterways mentioned, that life and property on the rivers was unsafe to a degree which could not be tolerated by the Government of any civilised country, and that criminals made free use of trade boats and the guise of river traders as a cloak for the purpose of commission of crime." At another place in the report it is stated "that the existence of a form of crime which looks much like a survival of the real Thaggi of old is also strongly indicated by certain facts . . . . from which it is clear that pious Mahomedans . . . . are systematically decoyed by their caste-fellows into making the "Haj" pilgrimage to Mecca, and then either murdered or looted when in transit on the river."

Further disclosures were that the losses of insured cargoes by country boats amounted to over 13½ lakhs in the five years 1900-1904. In consequence the Insurance Companies declined to accept further risks on cargoes of rice or jute except at special rates.

The main recommendations of the report were the notification of protected trade routes, registration of boats and crews, and establishment of a special River Police. I have been unable to find out whether these recommendations were accepted either wholly or in part, but the indications are that there was difficulty in finding the money to finance the proposed measures. It seems fairly certain therefore that no effective action was taken. In any case the policy of Government at the time was to encourage the railways, one of the reasons being that in the initial years of the life of the private railway companies Government undertook to guarantee profits. By comparison, policing and regulating traffic on the rivers was apt to be a costly affair, and unproductive of any direct or indirect return to Government. In the circumstances it is not surprising that the rate of decline of river traffic continued to accelerate in subsequent years till, on the upper reaches of the rivers at least, it practically ceased altogether.

A special word is necessary in regard to steamer traffic. In 1911 no fewer than 225 passenger steamers were listed as belonging to 6 companies. In addition, 19 cargo steamers were owned by 2 of the companies. It may be argued that these companies at least possessed the advantages of organisation and were not to any extent affected by crime. The decline of country craft might reasonably be termed their opportunity. Why then did not these

companies expand in proportion as the country craft traffic declined? The facts, as we know, are that even the steamer companies suffered a considerable decline.

The first part of the answer is threefold. First of all 5 of the 6 companies were railway companies. Their passenger services were intended mainly as ferry services supplemental to, and not in competition with, the railway services. The same principle applied more or less to goods traffic also. Secondly, though the steamer companies were free from the danger of river pirates, they had other difficulties to contend with. Wholesale theft of bamboos, put down by the companies to mark navigable channels, interfered seriously with navigation. In certain reaches these bamboos were removed almost as soon as they were put down, with the result that steamers frequently went aground. Complaints were numerous that country boats observed no fixed rule of the road, that they wilfully obstructed steamers in narrow channels and, in case of collision, claimed exorbitant damages. The safety of vessels was further imperilled by fishermen obstructing the fairway with nets and other gear. Thirdly, construction of the Ganges and Jumna canals completely dried up that river in the dry season thus depriving the Ganges, of a valuable source of water supply. The result was that whereas formerly the Ganges was navigable as far as Allahabad, it was now navigable only as far as Buxar and then only with difficulty by vessels of light draught.

But the real obstacle to steam navigation lies much deeper. The fact is that for eight months in the year, there is no satisfactory means of river navigation between Calcutta and the main Ganges stream in the case of vessels proceeding up-country. As we have seen, the main Ganges stream, about 400 years ago, used to flow down what is now the Bhagirathi distributary, and entered the Bay of Bengal close to Calcutta. The change of course of the main river towards the east caused the Bhagirathi and the other Nadia rivers gradually to deteriorate by deposit of silt at the close of each rainy season. This deterioration is such that the Bhagirathi which now has a depth of 10 feet or more in the rains, has, in certain years, scarcely one or two feet of water in the dry season. The Jalangi, next of the Nadia distributaries, has sometimes a greater depth, but is unsuitable for steamer traffic on account of other navigational difficulties, while the Matabhanga, the third and last of the Nadia rivers, has generally insufficient water to float any type of vessel except in the rains.

The result is that, except in the rains, steamer traffic from Calcutta port cannot proceed upcountry and back except via the

Garai distributary, involving an extra journey of over 200 miles, or by the long, circuitous route via Khulna or Barisal and Goalundo—a diversion of over 400 miles through narrow waterways which, at certain seasons, are choked with country boat traffic carrying jute and rice to Calcutta. The necessary economic conditions, therefore, for successful inland water transport—steady and continuous flow of import and export trade between seaport and hinterland—could not be achieved ; and independent steamer companies operating on the main Ganges river were, for eight months in the year, left with the hopeless proposition of competing with the railways for purely local goods and passenger traffic over comparatively short ranges of the river. In this, though they might, and did, have some initial success, they could not hope to maintain their position for long, for the simple reason that local traffic on the river bank was insufficient. Lastly, the expense and lack of facilities for transhipment between rail and steamer killed any chance of its developing to the advantage of the latter system.

The final blow was dealt when, at the end of the 19th century, shoaling of the Garai distributary and the construction of a low-level railway bridge across its head at Kushtia rendered this river impassable to steamers proceeding into the Ganges at any time of the year. Henceforward the two remaining steamer companies confined practically the whole of their activities to operations in the Sunderbans and Eastern Bengal—in which traffic they have never been seriously challenged by railway competition. These companies later combined, and now are in part railway owners themselves.

The history of river conservancy on the Gangetic rivers reveals the neglect into which they have been allowed to fall. In 1867 an Act was passed authorising the levy of tolls on the river Ganges between Dinapore and Allahabad. Under this Act a toll bar was established at Benares for the collection of tolls from vessels using the river. The income (between Rs. 7,000 and Rs. 8,000 in 1905) was divided amongst the districts of Ballia and Ghazipur, Benares and Mirzapur for river conservancy and in particular for the maintenance of a deep channel between Dinapur and Allahabad. The working of the Act was characterised by Mr. Bramley as admittedly unsatisfactory. "To begin with", he states, "the tax falls entirely on the boats above the bar, and thus the Allahabad and Mirzapur boats pay the whole of the sum realised, whereas it should be distributed over the entire shipping on the Ganges above Dinapur and, as at present

arranged, all the boats below this bar, i.e. those in the Benares, Jaunpur, Ghazipur, Shahabad and Ballia districts, who use this channel, escape toll charges altogether. The rates of toll are high and in fact so exorbitant that from a correspondence in the toll office it appears that the India General Steam Navigation Co., Ltd., discontinued their services to Benares on this account."

He goes on to point out the unsatisfactory manner in which the work is carried out, the lack of supervision, and the frequent complaints of extortion on the part of toll bar and trade checking subordinates, with the result that the toll bar, instead of being of benefit to trade, is a "distinct impediment".

The object of the operations in this area was to maintain a minimum depth of water of four feet, and in general this depth has been secured. The operations however are of insufficient scope for power vessel navigation. Bandalling is not employed, and hence in areas where there are shifting sands, such as on the notorious Ballia flats, at the junction of the Karamnasa and Ganges, the channel is so variable as to make navigation by power vessels a matter of difficulty and danger.

Between the years 1870 and 1900 nothing whatever was done by Government to maintain a deep channel in the Ganges river between Patna and Goalundo. About 1901, on the representation of the steamer companies, bandalling operations were resumed on some of the principal shoals, and a year or two later the Government of Bengal subsidised a small dredger for the Ganges. This policy has been continued in later years, but its inadequacy is evident.

The construction and improvement of the Sunderbans channels make interesting history. The natural channels were, in 1776, unconnected with Calcutta except by a roundabout route involving an exposed passage along the sea coast to the mouth of the Hooghly river. In the above year a certain Major Tolly entered into an agreement with the Directors of the East India Company to cut a navigable channel from the Hooghly to the Salt Water Lake "at his own proper costs and charges" and to pay therefor "yearly and every year ...... the yearly rent of one peppercorn". In return for this service he was given licence to charge tolls from vessels using the channel, which became known as Tolly's Nullah.

The opening of this canal marked the beginning of modern navigation of the Sunderbans. Originally insignificant, the canal was several times widened to cope with increased traffic demands.

In 1810 an old channel through the Salt Water Lakes was improved and made navigable under the name of the Beliaghata Canal. Between 1826 and 1831 a new route was opened between Calcutta and the Jamuna river, following the same course as the present Bhangar canal, the object being to relieve the pressure on Tolly's Nullah. Next the Circular Canal was cut from the Hooghly at Chitpur to meet the old Eastern Canal at Beliaghata, and this was completed in 1831. These canals were still choked with the increasing stream of traffic, and in order to relieve them, the New Cut was opened in 1859, leading from Ultadanga, a point on the Circular Canal 3 miles from Chitpur, to Dhapa on the Beliaghata Canal. Finally the Bhangar channel was canalised in 1899 for a length of 15 miles, thus completing the inner boat route which had been commenced in 1831.

All the above canals are boat canals only, and are not suitable for steamers, which still have to use the same exposed route by the sea coast which the country boats had to use before these canals were constructed. Indeed, not only does remarkably little appear to have been done to assist inland steamer traffic, but depth of water was not maintained even for country boats in these canals. Within a few years Tolly's Nullah had silted up to such an extent that boats could pass through it only on the flood tide, a state of affairs which still continues. This is all the more surprising since tolls were continuously levied on boats using the canal and these tolls were ostensibly for its maintenance and improvement. By 1902, tolls amounted to about Rs. 70,000 per annum, and it is probable that these would have been much greater had the canal been continuously navigable. Mr. Pointon, commenting on this, is driven to remark, "If we are to judge from the present state of the canal, it would appear that the surplus tolls received from the boatmen have not been devoted to the improvement of the canal or even any considerable portion of it to its maintenance."

The only remaining canal on which conservancy operations have been carried out on any scale, is the Madaripur Bhil route connecting the Kumar and Madhumati rivers. This route shortens the journey between Khulna and Madaripur by 89 miles, and is used by jute steamers in the rains. The Madaripur Bhil is a great swampy lake intersected by natural channels which were to a certain extent navigable even before they were canalised. The first steamer to go through the Bhil in 1894 was a stern wheeler drawing 5 feet. The next year a smaller stern wheeler ran more or less successfully from the end of August to the beginning of October. After this demonstration the steamer companies pressed

Government to canalise the Bhil. Construction was duly commenced in 1900, and the results are dramatically shown by the toll receipts from traffic using the canal. In 1900 they were Rs. 435, while 1904-05 they amounted to Rs. 45,393. In 1903 and 1904 the toll receipts (for the three navigable months of the year) represented a gross return of 3.4 and 4.4 per cent respectively on capital expenditure. In 1904 Government sanctioned a scheme to make the Madaripur Bhil route perennial, but not only has this desirable object not been realised, but the route has been allowed in recent years to deteriorate to such an extent that it is open to small feeder steamers only.

Next we come to the history of conservancy on the Bhagirathi. This, the most important of the Nadia rivers, was, as we have seen, once the bed of the main Ganges stream. The opening and maintenance of a navigable channel, either in the bed of the Bhagirathi itself, or parallel to it, is absolutely essential to the development of water transport in the Gangetic plain. Without such a channel, it will be impossible to connect the coalfields and ironfoundries of Bengal with the industrial areas of Bihar and the U. P. except by a disproportionately long and difficult route via the Sunderbans.

The question of the possibility of maintaining a deep channel in the Bhagirathi has been hotly argued since the latter half of the 18th century. The East India Company, as was to be expected, was very desirous of finding a direct route by river from Calcutta upcountry, which could be maintained in the dry season. To this end Rennell made a survey in 1764-65, but this survey did not bring any new route to light. In 1777 one John McGowan, possibly inspired by the success of Major Tolly's scheme, put forward a plan to keep the Bhagirathi channel open from the Ganges to its junction with the Hooghly at Nadia. Permission was given, but after two years there was little to show for his labours and the scheme was abandoned.

About 1783 the surveyor Wilford made a careful survey of the channels leading into the Bhagirathi and Jalangi rivers from the Ganges, and discussed the feasibility of opening a cut to allow navigation in the dry season. He concluded that this would be impossible owing to the great variations in levels at different seasons.

In 1794 the East India Company made another attempt to find a suitable navigation route, and James Hoare was sent to survey the Hurdum and Jamuna rivers to ascertain whether they could be made suitable for the purpose. His report was not unfavourable, and further investigation by the Surveyor General,

Colebrook, was recommended by the Governor General. In 1795 accordingly Colebrook surveyed the Jamuna, but found it unsuitable. He reported more favourably on the Hurdum and recommended a cut for a distance of about 6 miles, 20 feet wide and 15 or 20 feet deep, between the Hurdum and Ichamati. These proposals were referred to Rennell who commented very unfavourably on their prospects of success.

"Nature", he said, "seems to have adjusted matters very nicely, in respect to the capacity of Rivers, beds and their levels : so that any tampering with them in delicate cases (particularly when there is so great a periodical swelling and velocity of current) may be productive of much mischief."

The Court of Directors accepted Rennell's opinion, and no further attempt was apparently made in the time of the Company to seek a dry-weather route via the Nadia rivers.

The Bhagirathi nevertheless continued to serve as the principal rainy season channel for navigation. At the end of the 18th Century, expanding commerce to and from Calcutta again led to the question of keeping open the Nadia rivers which then showed signs of deterioration. Between 1800 and 1825 operations were commenced under an officer specially appointed for the purpose.

The Nadia rivers present, in the main, two problems. The first is the extensive shift of head each year: the second is the accumulation of silt in the river bed. At first attempts were made to stabilise the river heads, but this was ultimately found impossible. The engineers then fell back on the plan of making short connecting cuts, the utility of which however proved doubtful. To clear the silt from the river bed recourse was had to bandalling. The success attending these operations has varied. Figures show that roughly in three years out of ten the Bhagirathi has been closed to traffic: in another 3 the least depth of water is 1½ to 2 feet, while in 4 the least depth is about 2 to 3 feet. In the rains, the average depth is 10 to 14 feet. The opportunities for navigation on the remaining Nadia distributaries during the hot weather are much less.

In 1902 Sir John Woodburn, Governor of Bengal, decided upon a scheme of general improvement of the Bengal waterways, and instructed Mr. O. C. Lees, Superintending Engineer, to get out plans. Unfortunately Sir John died very shortly afterwards, and though the plans to canalise the Madaripur Bhil (which was part of the general scheme) were carried out, the remainder of the scheme dropped.

If the Bhagirathi cannot for any reason be successfully deepened by dredging or otherwise, the solution may be found in a navigation canal parallel to the river. Such a project is not new: many years ago it was proposed to make a canal from the Ganges at Sahibganj to the Hooghly river near Ramghat. Such a project would in all probability solve the difficult question of stabilising the distributary head. It might be found possible to combine such a scheme with a deepened Bhagirathi channel, but whether this would be feasible or not is for engineering experts to say.

CHAPTER IV

SOIL EROSION—ITS EFFECT ON RIVER NAVIGATION

The past two centuries have seen a great deterioration in the state of the rivers of the North and East Gangetic plain. Some which were formerly navigable have silted up at mouth ; others which afforded perennial navigation have degenerated to a mere trickle in the hot weather: not a few which used to be confined to fixed deep channels have fanned out in a series of broad shallow streams unfit for navigation.

Of the rivers in which deterioration has been marked we have already mentioned the Bhagirathi, the Garai and the Jumna, three rivers of first navigational importance, but deterioration is not confined to the large rivers. It is equally evident in their tributaries, from the largest to the smallest stream. Everyone acquainted with rural India must have noted in riverine tracts vast areas of unculturable ravine, or of great stretches of sand or boulders laid waste by rainy season torrents. The extension of these areas into the surrounding cultivation is gaining every year in rapidity. The report of the West Bengal Forest Committee quotes an old resident of Bankura as informing Mr. Shebbeare, Conservator of Forests, in 1925, that streams had in his memory been perennial which were then torrents in the rains and dry for the rest of the year. What happens in the tributaries and headwaters is likely to occur in the main rivers ; in fact, it is no exaggeration to say that the disastrous floods which have in recent years become practically an annual event in Bengal, have a large part of their origin in riverine areas outside that Province altogether.

It is nowadays well recognised that the root cause of this deterioration is the denudation of soil cover in the riverine tracts, particularly in the watersheds of the tributaries of the Ganges river. Where there is ground cover, such as grass, when the rain falls, the impact of each drop is spent on the grass: the water, clinging to the stalk, flows gently to the ground, there to be trapped among the grass roots, much as water is imprisoned in a sponge. There it stands until absorbed by the soil. As successive showers occur, the subsoil soaks up more and more water and the level of the subsoil water gradually rises. In the succeeding dry season this subsoil water either gradually drains away through springs; or rises by capillary attraction to the surface, where it nourishes vegetation.

Denudation of ground cover, on the other hand, allows the

rainwater to strike the surface of the bare earth. Its impact immediately stirs up silt. The presence of a very small amount of silt in suspension has the most remarkable power to prevent absorption of water in the soil. As a result, and since there is nothing to check it, the water at once begins to flow over the surface of the soil. This flow stirs up still more silt till finally we have the sight, so common in the rains, of a shallow, muddy flood bearing off with it a large percentage of the most valuable top soil of the land. As this water proceeds, it gathers speed, and near the river bank, where the slope is steeper, it begins to tear out deeper channels, and to form gullies and ravines, The erosion of rainwater on flat lands, termed "sheet" erosion, is not always apparent to the untrained eye ; but gully erosion is so spectacular as to require no demonstration to the observer.

But the damage does not end here. The waters of the river, swollen to overflowing with the muddy, gritladen water from the gullies, now gains sufficient velocity to roll pebbles, stones and pieces of kankar along the stream bed, scouring it out and undercutting the river bank, causing the latter eventually to collapse and mix still more solids with the torrent. The weight of these solids at any moment depends on two things—velocity and volume. Where velocity is slowed down, as usually occurs near the mouth the load is dropped to the river bed, the heavier particles first, then the lighter. Deposition however, particularly in the rains, is only partial—the vast bulk of the more finely sub-divided solids is carried out to sea and lost.

For those who prefer figures, there are some interesting statistics. According to Professor Fearnsides and Dr. Bulman the carrying capacity of a river varies as the sixth power of its velocity: that is to say, if the velocity is doubled, the carrying power is increased 64 times. What this means in practice has been tabulated as below by Mr. David Stevenson quoted in the Imperial Gazetteer. The figures refer to the speed of the river.

Inches per second	Miles per hour
3	0.170 will just begin to work on fine clay.
6	0.340 will lift fine sand. .
8	0.4545 will lift sand as coarse as linseed.
12	0.6819 will sweep along fine gravel.
24	1.3638 will roll along rounded pebbles 1" diam:
36	2.045 will sweep along slippery angular stones of the size of an egg.

The typical course of an Indian river can be divided into three stages. The first is from its source to the foot of the hill or mountain range where it rises, the second is from the foot of the

hills to the apex of its delta. The third is the deltaic stage from the delta apex to the sea.

In the first stage the volume of water is comparatively small, but the fall rapid and the velocity great. The river at this stage has great erosive power, which is assisted by the steep slope of the hillside. Considerable quantities of solid matter are carried down stream, earth, bajri, pebbles and large stones, the motion of which is assisted by the steep fall of the river bed. On emerging from the hills the river immediately loses much velocity ; it is unable to carry the stones and boulders any longer. These therefore drop to the bottom and may be seen in the form of great screes at the foot of the mountains.

In the second stage the river becomes a quiet meandering stream, bearing with it a large volume of silt in suspension, and receiving still more from the muddy waters of each tributary. As it flows along it erodes out the bottom of its channel, sinking lower and lower below the level of the surrounding country. When the latter is of hard clay or kanker, the permanent banks of the river stand out as perpendicular cliffs often 40 or 50 feet in height, and sometimes as far apart as 9 or 10 miles. Within this large space the river is generally unstable, swinging its deep channel from high bank to high bank more or less gradually over a period of years.

In the deltaic stage the river, by reason of a sudden check in the fall of its bed, is unable to maintain sufficient velocity to carry its load of silt except in the rains. The silt is therefore largely deposited. Slowly the river builds up its bed to the level of the surrounding country and frequently beyond it. Eventually there comes a time when a strong flood causes the river to breach its banks, and fan out over a wide area in a number of shallow streams radiating out from the point of the burst towards the sea. The forces thus brought into play defy the best that modern engineering can do to confine them: the cure is to be found not in strength, but in cunning. It is useless to try to stem the torrent, but it is practicable, within limits, to prevent its occurring.

The last scene in the life of an Indian river is a wilderness of forest and swamp at the end of the delta cut by an intricate network of tidal creeks. Here the silt dropped into the sea by the river has accumulated enough to raise new land above the level of the sea. But even so, only a portion of the silt is dropped. The great bulk of it is carried right out to sea and lost. The amount of silt carried out to sea by the Ganges may be guaged from the fact that its waters discolour the Bay of Bengal 150 miles from the shore.

It must be remembered that deltaic conditions may occur even higher up than the delta proper, and may be caused by a check in the waters of a river by a sudden drop in the rate of fall, or by the water being held up by a cross-current from a tributary. In such conditions deterioration occurs far upriver from the delta. Once the process begins, it tends to spread. The river, no longer confined within definite banks, swings from side to side from year to year over a wide range, developing in place of a single bed, a maze of small channels ; becoming in the end destructive to agriculture and useless for navigation.

In the United States of America and some other countries, experiments have been carried out for the purpose of estimating the annual soil loss through erosion. Figures of soil-loss for India are still incomplete, though some magnificent work in this connection has been done by Dr. R. M. Gorrie. In the United States of America the soil loss from bare soil in single storms has been estimated to vary between 2.6 and 44 tons per acre over a period of nine hours only. Where the soil was covered by grass, the loss ranged from nil to .2 tons. In the whole of the United States of America it is computed that at least 2000 crore maunds of solid matter are carried annually to the sea by rivers. It is certain that India size for size, suffers no less damage.

Some idea of the volume of solids carried by the Gangetic rivers however can be had from the fact that the Ganges Brahmaputra delta, consisting of 50,000 square miles, has been raised 400 feet entirely by deposit of alluvium. The Rev. Mr. Everest calculated that the Ganges discharges nearly 637 crores cubic feet or 690 crore maunds of silt per annum at Ghazipur, and of this amount 96% is brought down during the four months of the rainy season. The colossal quantity involved may be faintly conceived when we realise that a thousand boats each of 1000 maunds cargo capacity making each one journey a day, would take nearly 20 years to carry what the river does in four months.

The total mass of mud brought down to the sea by the Ganges and Brahmaputra rivers was estimated by Sir Charles Lyell (vide Imperial Gazetteer) to be at least six or seven times as much as that discharged by the Ganges alone at Ghazipur. This given therefore at the lowest estimate about 4000 crores of cubic feet or roughly 2,700 crores maunds of solid matter spread over the delta, or deposited at the river mouths, or carried out to sea each year. Such is the loss to the rich alluvial plain of the Ganges caused by the violent floods of the rainy season.

Violent floods in the rainy season are of necessity followed by

droughts at other times of the year. This is inevitable: the water which should have been trapped where it fell, absorbed by and stored up in the soil during the rains all ran off immediately into the river and was carried to the sea and lost. There is insufficient water left to produce the springs from which the river should be nourished in the hot weather. Thus, instead of the river being perennial we find it seasonal ; instead of there being a reasonable increase of volume in the rains, it has become a destructive torrent ; instead of its volume being merely lessened in the hot weather, it is reduced to a mere trickle, or, in extreme cases, to a dry river bed.

It needs no technical knowledge of navigation to realise that for navigation one requires first, a minimum depth of water, and second, reasonably slack water. By this is meant that the speed of the current must not be excessive, in order that the vessel shall remain under control. It is therefore readily seen that the conditions produced by denudation of the soil cover tend to produce conditions difficult for navigation.

The deterioration of rivers of the Gangetic plain above described has been very much more marked during the past two hundred years. The reason for it is deforestation.

Forests are one of the best forms of ground cover. Where trees are close together and of branchy habit, they form a canopy over the forest floor, protecting it against the impact of the rain. The collection of scrub, dead leaves, twigs and bark which litters the forest floor, further protects the soil, though it is not as efficient as grass in holding up the flow of water. Tree roots however are much more effective than grass in preventing erosion ; they knit the soil together, particularly on steep slopes. Lastly trees cast a deep shade: the sun cannot penetrate except in small measure to the forest floor. Evaporation of surface water is thereby prevented, thus enabling the soil to hold its moisture longer. Taken all in all, forests are undoubtedly the most valuable protection of all against soil erosion, and this is especially true in the case of mountain slopes.

In pre-Vedic times, the greater part of the country was covered by dense forests which were gradually opened out to cultivation by Kshatriya settlers along the banks of the main streams and rivers. At that time the Ganges was in all probability a river of the class of which the Amazon is the sole remaining survivor in the world—a deep sluggish stream flowing between deep belts of almost impenetrable forest. If the Chinese traveller Fa-Hian, who visited India in the 4th century is to be believed, these

conditions were not altogether non-existent even then, and it is noteworthy that he records that the climate of the Gangetic plain was temperate—neither hot nor cold.

The extinction of the forests was greatly hastened by the invaders from the north—nomadic tribes, who fired forest and grass-land alike, leaving a trail of destruction in their wake. Up to the time of the arrival of the British in India this process of forest clearing had reached such a stage that, according to the writer on the subject in the Statistical Atlas of India, the forests had already been reduced in several areas below the minimum necessary for the country's well-being.

British rule, instead of putting an immediate stop to further devastation, gave in the beginning a new impetus to destruction. In general it may be said that the forests of Northern India were, before the development of trade with Europe, of more value as grazing areas for cattle and for charcoal and firewood, than as producing areas for timber. First, there was little demand for timber for any purpose, and almost none at all for commercial purposes. Second, timber is one of that class of commodities, such as coal and cement, of which the cost at production site is small in comparison with the cost of handling and transportation over any distance. In such circumstances there was little scope for a market beyond a small local demand for timber for building or for making agricultural and other implements.

Prior to 1750 therefore, deforestation was occasioned almost exclusively by the demand for more agricultural land. With the arrival of the British and the spread of the domination of the East India Company, the process was not only accelerated, but to it was added another compelling force, namely, the growth of a definite trade in timber. This trade was slow in growing: it did not show itself as a major trade till about 1850, when export to England was beginning to be developed. Both teak and Morung sal were already on Lloyd's list of the world's seven best woods for shipbuilding at the time of the Great Exhibition, and teak was by then beginning to challenge English oak for the construction of wooden sailing vessels. But the demand was not for shipbuilding timber alone. The great rise in the standard of living in England and the continent induced by industrial development led to a greatly increased demand for wood for furniture and turnery, and this demand lasted until the advent of the iron ship, the cheap veneer and the decline of Victorian taste for ornament.

In such circumstances it is scarcely surprising that the remaining merchantable forests of Northern India were felled with

renewed vigour, without a thought for the future. The question of whether or not a forest was merchantable largely depended on whether there was any means of conveying the timber to the sea. It is easy to see that the forests adjoining river beds were the most vulnerable. But it was not till the advent of the railway that the forces of devastation reached their full violence. The railways created a new demand, not only as affording a means of transport but also by reason of their requirements for sleepers and for construction works—demands which were frequently supplied in a wasteful and reckless manner.

Evidence of this is in every Gazetteer. Williams, in his *Memoir of the Doon* writes of Dehra Dun in the period 1839-1843, "Every one continued to hack and hew away at the trees as he pleased, only paying certain dues to the farmer, in the event of the wood being exported ...... Reckless waste was inevitable, and the fine Sal forests began to disappear rapidly. The absence of conservancy was absolute. The district still abounded in fine trees 100 or 200 years old and upwards. All these fell before the axe, and probably the rest would have gone with them had the roads been a little better." The Imperial Gazetteer states of the history of the Bengal forests that it "is similar to that of other forests in the parts of India. When the East India Company first began to acquire sovereign rights, its officers were naturally impressed by the great extent of forests rather than by the benefits to be derived from them ; and for many years their sole aim was to expedite their conversion into cultivated fields. Many of the best forests were alienated and reckless exploitation ran riot."

So rapid was the work of destruction that there begin to occur in certain areas sudden shortages of timber. It was only when failures to meet local demands for public works were brought to notice that the necessity of conserving the forests was gradually recognised. Eventually in 1878 the Indian Forest Act was passed by which large areas of forest were reserved to the State, while other areas were 'protected'. But even so, the action was inadequate. Sir Herbert Howard's note on Post-war Forest Policy in India shows that State forests amount to only 18% of the total forest area in India. In the private forests mismanagement and reckless felling continued. The District Gazetteer of Gorakhpur, published in 1909, states that for many years the private sal forests had been ruthlessly felled to meet the growing demand for timber created by the advent of the railway. The extent of the demand is demonstrated by the figures of export ex-India alone.

The value of the trade in 1882-83 was Rs. 7,51,600, and by 1904-05 it was Rs. 79,76,672—an increase of well over ten times. The Report of the West Bengal Forest Committee made only a few years ago, reveals that a state of serious mis-management still exists in the forests of Western Bengal, as a result of which the forest area is rapidly diminishing.

The late war greatly revived this reckless waste in private forests. Even strict Government control of price and supply of timber did not prevent the ruthless felling of anything saleable in the way of wood, either for construction or for fuel. Owners of mature mango groves have found that the value of trees when cut is more than they would get from the fruit for the rest of the life of the tree: there has been a great clearance of old groves and the complaint is now often heard that *desi* mangoes can now be obtained only with difficulty. Some of these fellings were admittedly overdue, but that there has been a further serious orgy of reckless waste is only too clear, and a timber famine in many rural areas is now inevitable.

Private ownership and forest management do not appear to be suited to each other. Human life is short: a forest requires to be worked on a rotation of between 50 to 150 years. No private owner, and least of all a semi-ignorant villager, can be expected to wait all this time. Regarding him, Sir Herbert Howard says, "As a rule he aims at realising the greatest profit from the forests and this results more often than not in felling everything saleable in a comparatively short period, resulting in the more or less complete devastation of the forest. Even private owners with family traditions to uphold may deliberately realise the whole capital invested in the growing stock (which is devastation so far as forestry is concerned) because other investments offer an apparent and immediate better return on the capital than forestry. Even the most enlightened private owner, at some time of particular expense or stress, finds his private interests so opposed to the interests of the forest that the forest is sacrificed to a greater or less extent."

So far as the navigability of rivers is concerned, the absence of forests has two effects. The first is that as already pointed out, rivers tend to become more of the nature of rainy season torrents than perennial streams. The second effect is that where belts of trees on the banks of a river in its second stage are cut, the river is thereby enabled to erode out its banks sideways. The result is that, as can be seen in the Ganges *khadir* anywhere in the Doab, the main banks of the river are miles apart, and in between, the

river swings and sways with great annual change, spreading itself out into a shallow flood filled with shifting sand banks. The danger of such river action is recognised by the Forest Department whose officers are under instructions not to cut trees or bushes within 100 yards or so of any nullah or stream: this simple device of leaving a belt of forest on each side effectively prevents the stream from eroding out its banks. The sole reason for the unusual navigability of the Amazon is the deep belt of almost impenetrable forest which, undisturbed from the beginning of time, has confined it closely on either hand. As I have before opined, it is likely that the Ganges was at one time similarly confined, and there can be no doubt that its navigation in such conditions must have been much easier than it is now.

But the trouble does not end with the cutting of trees. Much deforested land is, by reason of gully erosion, unsuitable for cultivation. Such land, after denudation, if left to itself and allowed a reasonable chance of regeneration, would rapidly restore its own ground cover. But no such chance has ever been afforded. No sooner was an uncultivable area clear of trees than it was invaded by the hordes of cattle, many of them useless, which encumber every Indian village. It is in fact on record that a number of forest areas were deliberately felled to obtain clearances for cattle grazing. Stall feeding of Indian cattle is at present out of the question owing to the large number of animals involved. On the other hand, grazing grounds are in the great majority of cases of insufficient area to stand up to the number of cattle involved. Where there are sheep and goats the problem becomes worse than ever. Two evils follow. The first is that the grass never has a chance to grow: the second is that the continual kneading of the bare earth in the rains by the feet of thousands of cattle produces a chemical change in the soil, and by preventing aeration causes it eventually to become practically incapable of growing anything at all.

Production of grass then drops: the more it drops, the more the cattle wander over it in search of herbage, and the more the soil deteriorates—a really vicious circle. The scarcity of good grazing grounds, and the demands of agricuture lead to a concentration of animals in ravine country or in small nullahs on the outskirts of the village: thus it comes about that the evils above mentioned are most violent in precisely those very areas where they are likely to cause most harm.

The evils of erosion are generally recognised at the present time but there are many difficulties in the way of an adequate solu-

tion. One of these is finance, and I hope to show in chapter 6 that inland navigation, if revived and developed as a state monopoly, will be a valuable source of revenue for the most important cognate work of arresting further river deterioration.

CHAPTER V

THE REHABILITATION OF RIVER TRANSPORT

I. The Physical Aspect

The subject naturally falls under two heads—first, the physical, and second, the economic.

Under the first head, we have seen that the rivers of the Gangetic plain in the past two hundred years or so have undergone serious deterioration. Under the second head, it has been shown how traffic on the river has suffered almost total extinction by reason of railway competition.

Rehabilitation therefore involves action in two spheres—first, river conservancy ; and second, economic development. It is clear that it is no use proposing grandiloquent schemes on the economic side for the development of river navigation, unless there is water enough to float our boats. The question of river conservancy therefore comes up first for discussion.

Depth of water, absence of violent current and stability of the river bed are our requirements in a nutshell. There are various ways of obtaining these desired objects, and in general any measure which will achieve one of these objects will usually assist in promoting one or more of the others. Further, the majority of the measures which will benefit river conservancy, are also of the utmost importance in the improvement of agriculture and its allied subject of irrigation.

As we have seen, the prime cause of the deterioration of the rivers is the denudation of ground cover, particularly destruction of the forests. Obviously therefore reforestation must play an important part in any long term policy of river rehabilitation, but as this question has an important bearing on practically all other methods of achieving results, a discussion of it will be left till the last.

There are many methods of river training and conservancy. Some of these are direct—purely engineering jobs ; others are indirect, and involve agricultural or silvicultural methods. The first of the engineering methods is a system of buoyage, followed by spur-work and bandalling ; next come in turn dredging, construction of retaining embankments, and construction of hydro-electric dams. On the agricultural side there are contour ploughing, contour ridging and ditching (also used in silviculture) and terracing of hillsides and slopes. The above does not exhaust all the methods, but they are the ones in common use at the present time.

The simplest method of ensuring a deep-water channel on an Indian river used for navigation, is a system of buoyage. At the end of the rains, when the river level begins to fall, the water becomes confined between shoals and sandbanks, and scouring begins to take place. By strict direction of all shipping into fixed channels, this scouring is materially assisted by the wash set up by paddles or propellors, and by the passage of the vessel at speed. As the level falls, so does the bottom scour out, so that the actual depth of water in the channels remains constant.

This fact was amply proved by the experience of the Inland Water Transport in Mesopotamia during the 1914-1918 war. There on the Tigris, before the I.W.T. took over, vessels using the river were allowed to choose their own routes. The result was that the river, in many places, formed no stable channel, and groundings were frequent. The I.W.T. instituted a complete buoyage system with the results above stated. Between Ali Gharbi and Kut during 1917 the river level was at Ali Gharbi 2 to 3 feet lower than during the same period in 1916, but an average least depth of 6 feet was maintained over the whole range as against an average of only 5 feet in 1916.

On the Tigris it was found that clay would not scour out by the above method, and had to be dredged. Channels once scoured out, however, could be expected to maintain their navigational conditions fairly constantly for a period of a few weeks.

The scour above described is probably best set in motion by propellor-driven craft. The engineering problem caused by propellors working in sand-laden water has to a very great extent been eliminated by the introduction some years ago of cutless rubber bearings.

Where buoyage alone proves insufficient, scour may be materially assisted by the process known as spur-work. As its name implies, this consists of short spurs projecting from the river bank, either at right angles to the line of flow, or angled downstream. These spurs may be constructed of a variety of materials, varying from a simple row of posts to a pucca masonry structure. In all cases the object is the same—to cause obstruction to the clear flow of water along the bank : this both prevents erosion of the bank, and encourages deposition of silt between the spurs. The result is that the banks of the stream are built up : the main channel is constricted, and in consequence heavier scour is ensured, thereby excavating out the river bed.

Spur-work is frequently ineffective, particularly where the river is very wide and shallow, and it is uncertain which of several

channels is the main one. In such cases bandalling is frequently effective.

Bandalling is a process well known to rivermen in certain parts of India. It may be indigenous, though there is some evidence that it was introduced into India by the engineers of the East India Company. The process is mentioned in a report by Lieutenant Douglas on the river Jumna prepared in 1840, though no details are given. Details of a process resembling it are to be found in a *Memorandum upon the Improvement of the Navigation of the Ganges between Allahabad and Revelganj,* by Mr. F. A. Reade, Commissioner of the Benares Division, written in 1847. According to him the hard sandbanks below Sultanpur and near Mirzapur, which had always proved a serious impediment to navigation, had been overcome by this simple process. "Major Hill," he states, "effected a passage through the obnoxious shoal, by a process similar to what (if my memory serves me) is called 'jobbing' in the Thames. He formed a fleet of boats in the shape of a cone, the apex down stream, and with a narrow opening between its points, at the lower side of the sandbank. At this point delvers jobbed or excavated a passage, and thus proceeded upward through the shoal. Their weapons were a common sharpened paddle secured to a stake or bamboo. The cut, once made, was soon widened and deepened by the operation of a known law of rivers ; the superincumbent pressure of water being increased by the river always seeking a new channel, being guided into one excavated for it. In this manner a barrier, which it would have been worth the while of the steam companies to remove at the cost of thousands of Rupees, was effectively disposed of at an outlay of about Rs. 27/-."

The above process, though closely resembling bandalling, is not quite the same thing. But later on in his note, Mr. Reade goes on to say,

"Colonel Pew, with the commendation I believe of a very competent authority, Major Boileau, has suggested the trial of a simple apparatus. I do not know a better name for it than *screen bandels*. The principle is to induce the river, to assist in forming a channel and adhering to it. The different exhibition of sands, the greater extent, and the more difficult application of means, compared with the hard sand bank above treated of, renders a somewhat different process necessary. These bandels must necessarily be of greater length. The apparatus will consist of a fleet of Boats, at some distance from each other, in two lines ; with ropes to each, stakes at intervals, and hawsers passing from end to end, to which

will be fastened bunches and bundles of the common Bhyr koonta (or palla thorn bush) which will be embedded in the sand. The shallowness of the water will render this easily practicable. The course of the stream will have been previously ascertained ; and the effect of judicious location of the lines of bandel, will be to induce an inflection of the current, from the one to the other, so that eddies may be formed behind the screen in which the sand will be deposited, while the current (with or without aid) clears the intermediate channel. This process, it is considered, will both effect a channel for, and indicate it to, the navigator."

The above description is not very clear, but it will be more readily understood after reading the following description of modern bandalling as applied by the Inland Water Transport on the Mesopotamian rivers in 1917-18. Bamboos up to 20 feet in length and 3 to 4 inches diameter were driven into the sand 18 to 24 inches apart. Two rows were arranged, one at each side of the channel which it was desired the river should take. The two rows were placed slightly closer together at the downstream end than at the upstream end. Each line of bamboos was 150 to 200 feet long. Next, across these upright bamboos, other bamboos were lashed and the whole was strutted by saplings 8 to 10 feet apart. Mats were then placed on the weather or upstream face of the line of bamboos, extending 3 to 4 feet beneath the surface.

The river was thus compelled to flow between a series of screens so arranged as to form a succession of cone-shaped channels. The velocity of the river was thus slightly increased as it approached the foot of each cone, and, as it discharged into the next cone it swirled and eddied out between them : the water so escaping spread out behind the bandals, where it immediately lost velocity and dropped its silt. In this way the river was induced to form sandbanks behind the rows of bandals, and to scour out a deep channel in between.

The above is a particularly scientific and thorough method of bandalling, of which there are many variations known. As an example, I may quote the method used by a forest officer in Burma utilising close fences of bamboos only : the fences catch up the many kinds of small rubbish brought down on every jungle rise ; this forms a barrier which checks the flow of water and causes the silt to be deposited beyond it. In this way successive floods not only build up embankments but raise the level of the surrounding country. The peculiarity of this method is that the stream does not scour its bed, but raises its own banks : this method therefore

will have particular interest for us later when we come to consider afforestation of river banks.

Bandalling has long been used on the Ganges. The Administration Reports of the U. P. between 1880 and the end of the century make frequent reference to the fact that navigation was by this method satisfactorily maintained on the Allahabad-Dinapur section. A minimum channel depth of 4 feet was aimed at, and this appears to have been achieved with the exception of 1886-87 when at one place the depth was reduced to 3 feet 7 inches. The cost of these operations varied between 11 and 16 thousand rupees each year for the period above quoted.

The results of bandalling on the Mesopotamian rivers have been recorded in the official account of the I.W.T. The water selected was various stretches between Baghdad and Kut, a total distance of 213 miles, with an average fall of 6.34 inches per mile, which is slightly greater than that of the Ganges above Benares. The velocity of the river varied between 1½ to 2½ knots in the low water season, and between 2½ to 4½ during floods increasing to over 5 knots at sharp bends and in narrow channels. This velocity is certainly not greater than that on the Ganges.

Bandals on the Tigris were found useless when the current fell below a certain velocity, not only because the silt in suspension was small, but no scour set up.

Bandals, it was found, will not always make the river take the course required, no matter how early in the season operations are started, nor how well bandals are placed, and it is better to accept the apparently unnatural course of the river than to close the river altogether in a vain attempt to conserve an ideal channel.

Bandalling is not always successful in certain local conditions. Mr. Pointon is of opinion that it has not been of much use in the Nadia rivers where, in order to prevent flooding, bunds have been erected at many places on the river banks. He considers that these bunds largely neutralise the effect of bandalling, since by preventing the water from overflowing into the surrounding country, they cause all the silt to be dropped on the river bed, thus causing a greater deposit than would otherwise have been the case. For this reason, he says, in spite of bandalling for well over a century, these rivers have increasingly deteriorated.

Bandalling therefore has its limitations, but where conditions are suitable it is a cheap and efficient method of deepening a river channel. On the Tigris it was found of the very greatest assistance in improving and maintaining channels, and in many cases

actually forming them, and it fully justified the expense and energy that were expended upon it.

There is no doubt that modern engineering experts could devise an improved method of bandalling, using perhaps a flexible wire mesh instead of mats on bamboos. Mr. Reade's plan for a moveable bandal, using boats to float it is capable of considerable development. The modern bandal might be supported by light pontoons with floats at intervals in between, and weights at the bottom to keep the mesh perpendicular. It does not appear to be necessary to have an absolutely impervious surface, as witness the forest officer's method above referred to. Modern experiments in aero- and hydro-dynamics have established that even a wide mesh acts as a substantial barrier to a current of air or water and that a thin wire offers more resistance than a thick one. This is, however, getting somewhat beyond our province.

Where bandalling is ineffective for any reason, it is necessary to resort to dredging. Two classes of modern dredgers are the bucket dredger and the suction dredger. The former drives an endless chain of buckets, in principle the same as the Persian wheel, and these, scraping the bottom, bring up the mud and silt. The suction dredger sucks up the mud by means of powerful pumps, and discharges it through a long pipe which is sometimes several feet in diameter. The latter method is naturally much quicker. Neither type can deal with rock, which usually has to be blasted. Where there is only fine sand to deal with and a constant current can be maintained, as on the Ganges river, dredging is greatly simplified since in this case the river arranges its own dispersal of material. In this case there can be used a third type of dredger, namely, the jet dredger or jet agitator. This is merely a development of the method whereby channels are scoured out by jobbing or by the passage of vessels. A powerful jet is used to cut into and stir up the silt ; this is then carried downstream in suspension. Jet dredgers have been found very useful on the Nadia rivers, and it is the opinion of Mr. Lumsden, formerly Chief Engineer of the I.G.S.N. Coy., that a sufficient number of them could maintain depth in the Bhagirathi without any other assistance provided this river were once deepened sufficiently to admit mechanically propelled vessels in the dry season. Mr. Pointon also held this view. In the monograph previously referred to he says:—

"It should be understood that the trouble in navigating these large rivers in the dry season is principally caused by the main channel breaking up at certain places into two or three small ones......

"As a rule there would be no great difficulty in attracting sufficient water into one channel for a time as the shoals, being of sand, are easily operated upon with the assistance of the currents. Such shoals may be deepened temporarily or permanently for the dry season by various methods, viz., by bandalling (open or closed), light dredging, jet agitators and stern wheelers, and stern wheelers alone, passing over the shoals a number of times. Steamers themselves undoubtedly play a most important part in keeping the channels open, so the greater the volume of traffic, the less work is required from other artificial means. This specially applies in the case of spill rivers, where there is a large volume of water in the main rivers to draw upon, or attract."

Mr. Pointon goes on to observe that each shoal should be carefully examined and its peculiar local characteristics thoroughly understood before commencing dredging operations.

The construction of retaining embankments to rivers, though in general assisting a river's stability, is not of particular interest in navigation. These embankments are usually at some little distance from the dry weather channel, to allow for expansion of the river in the rains: sometimes spurs are run out at right angles towards the river. Embankments do, it is true, help to some extent in confining the river to a regular channel, but in the main, they are of more interest from the point of view of flood prevention and agriculture. Such embankments are expensive, and it has been shown time and again that they are of no avail against a sudden swing of the river, though they are able to stand up to normal floods unaccompanied by any violent change in the river's direction.

The construction of hydro-electric dams, or indeed, dams of any kind, are of the greatest importance to navigation. Contrary to what may appear, a dam need not diminish the flow in the cold weather. The storage which accumulates during the rains may be let down in regulated quantities, which may be greater than the normal cold-weather discharge. This however, is frequently not possible if the storage is let down irrigation channels, and as the aim of hydro-electric engineers must be to include a canal irrigation system in their plans, the fact must be accepted that only in selected cases will such dams add to the cold-weather discharge, and thus aid navigation.

The Provincial Governments of the U. P. and Bengal have under consideration schemes for further dam construction in the near future. None of these is likely to affect navigation to any great extent, with the exception of the Rihand Dam project. This

scheme proposes to impound 9 million acre feet gross in the Rihand basin in district Mirzapur by a 250 feet high dam across a gorge. The capacity of the installed plant is expected to be 150,000 k.w. In addition to this, the gross annual storage will enable a perennial flow of 6000 cusecs, which, after power generation, will be used partly for supplementing the existing water supplies to the Son canals and partly to improve navigation on the Ganges below Patna.

This project, which is of the utmost interest from the navigational point of view, has been considered, by reason of its regional scope and size, to lend itself to development by a Federal organisation rather than by Provincial agency.

I have referred to various agricultural methods of preventing or reducing excessive run-off of rain-water from the soil. Anything which tends to prevent soil erosion has a distinct value in stabilising our rivers, but details are rather beyond our scope, so I shall do little more than refer briefly to these methods. The first is terracing, and this needs no explanation, though it must be mentioned that there are various refinements possible, such as watt-bandi, in which the terraces are formed like shallow saucers: also terracing reduces greatly the run-off even where the original slope was very gentle. As we have seen from our river data, even a slight fall causes great water velocity.

Contour ridging and ditching are methods of checking the run-off which need no elaboration. The ridges may be small—say, only a foot or two high, or they may be comparatively large bunds. Contour ditching is sometimes used as an aid to tree-planting in eroded soil. Reports of such experiments may be found from time to time in the *Indian Forester*. Generally speaking, the ditch traps a certain amount of fertile silt in which the saplings can be established.

The last of the agricultural methods is contour ploughing, which is, in effect, a variation of contour ditching. This method is much in favour of the Tennessee Valley as a method of preventing soil erosion. It postulates large-scale farming, which, unless some means can be found to persuade the Indian villager to abandon his small field methods, makes it somewhat difficult to introduce into India. The efficacy of the method is undoubted.

Back of all these methods of preventing run-off with consequent soil-erosion, lies the necessity for afforestation. Restoration and development of arboreal cover in the proper areas is without doubt the best and most effective method of restoring our rivers

to a stable condition, and thus improving their navigational facilities.

In the first place a word of warning is necessary. Forests cannot entirely prevent floods ; they can only mitigate them. The volume to which floods will be reduced by forests is a subject of controversy. Dr. Kamalesh Roy, River Physicist of the University College of Science, Calcutta, quotes the U. S. Civilian Conservative Corps that their work over a period of two years in 141 watersheds throughout the U.S.A. indicates that the volume of run-off can be reduced 20—25% through the use of erosion control methods. Dr. Roy considers this a probable maximum, and pins his faith to detention dams as the principal means of preventing floods, e.g. on the Damodar. Whether or not these estimates are correct, it is certain that afforestation is not a universal panacea in respect of flood volume. Forests are useful not so much because they diminish the volume of a flood, but because they rob it of its destructive effects.

In short, the main value of forests is to prevent soil erosion. In this particular sphere their worth is undisputed.

For river training, there are two ways in which forests can be of use. The first is in diminishing run-off and erosion caused by rainfall in the catchment areas of tributaries and parent streams. The second is to act as a retaining belt to the main stream in the second and third stages of its life.

The first of these two uses postulates the development of forests in the Himalayas, on the Central India Plateau, and in the hills of Bihar and Western Bengal.[1] The second requires a forest belt on each side of plains rivers in the alluvial tract between the high banks, wherever this may be practicable.

One of the main difficulties in the way of such afforestation is the counter claims of agriculture. Large-scale afforestation of these areas without reference to the needs of agriculturists would entail displacement of considerable numbers of the rural population. This is clearly undesirable, except as a last resort in serious cases. Where afforestation is not possible, recourse can be had to the agricultural counter-erosion methods outlined above, and in addition, there can be adopted the efficacious method of closing certain areas to grazing.

Closure of an area to grazing does not by any means entail such hardship to the villagers as may at first sight appear. Anyone familiar with hill cultivation knows how bare are the hillsides, and with what difficulty grass grows on them. This is the result of continuous over-grazing. By closing an area to grazing, the

capacity to produce grass is in a very few years restored, so that an increase of five times the production is not only possible, but has frequently in practice been achieved. The method involves hand-cutting of the grass, and stall-feeding of the cattle—a method which is not such a burden as it would be on the plains, owing to the smaller number of cattle kept. It is noteworthy that in the pargana of Jaunsar-Bawar, where the people are commonly supposed to be backward, in several areas the villagers have, entirely of their own accord, and without any outside prompting or assistance, evolved and adopted this system with very beneficial results.

Though grass is good in preventing run-off, it is poor in preventing erosion, especially on steep slopes. A happy compromise, therefore, would be to combine forest and grazing areas. By this system, areas would be closed to grazing, but open to grass-cutting till the trees were of sufficient size: then the area could be thrown open to grazing until such time as the tree-cover prevented further growth of grass. When the forest reached maturity, and was felled, the process would again begin.

On the plains, afforestation of waste lands on a large scale is in contemplation in the United Provinces, while Bengal is preparing to launch a Damodar Valley project on the lines of the Tennessee Valley scheme in the U.S.A. In Bengal and Bihar attempts are being made to persuade the owners of private forests to hand them over to the State for management. The areas on the plains, however, which most directly affect navigation, are those alluvial tracts immediately bounding the rivers.

Such areas are at present lying practically waste. They contain only a few trees and bushes, and are generally covered with *jhao* or long grass. They vary from the wet swampy soils of the Doab *khadir* to the dry sandy stretches known in the east of the U.P. as *manjha* lands. The *khadir* areas support a little cultivation—mostly sugarcane. In general the *khadir* can be divided into two areas—that in the immediate vicinity of the river (termed *ihtamali*) and that close under the high banks, termed *ghair-ihtamali*. The latter only is culturable, the former not. Much of the area is covered with marsh and *jhil*, and wild animals, particularly panther and pig, are numerous. As may be imagined, the whole area is very malarious, and for this reason there is only a very small permanent population.

The *khadir* areas are generally looked upon as a grazing reserve for cattle, but their importance in this direction is sometimes exaggerated. Cattle are rarely left overnight there, owing

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to the depredations of panther, and the danger of malaria to the cowherd. This entails long daily journeys, the fatigue of which considerably detracts from the benefit of good grazing grounds. Generally speaking, this area would be of infinitely more value to the inhabitants of the neighbourhood and the State as a forest reserve and hay-producing area combined, than as a grazing ground and casually cultivated area as it is at present.

Since the war, the few remaining trees in the *khadir* and on the high banks confining it, have been ruthlessly cut to meet the extraordinary demand for timber at the present time. The result is a recurrence of erosion at certain places in the high banks. The *khadir* is now likely to be extended considerably beyond its present limits unless means are found of stopping the process. This is a further strong argument for State intervention.

Trees are not always grown with ease in *khadir* areas. The soil lacks organic matter: cultivation can be carried on at most for three years or so, after which period the soil must be left for a number of years to regain its fertility. Forest plantation was attempted some years ago in the *khadir* in Meerut district, but was not very successful. It has been shown however, that different techniques have different degrees of success in such areas, and trees certainly can be grown, particularly the acacia and dalbergia species. An example of a successful technique adopted in the Punjab in such areas will be found in an article in the *Indian Forester* of June 1945.

The action of a belt of trees close to the river bank is in effect that of a perfect bandal and spurwork combined. The flood water is unable to tear deeply into the soil, but spreads among and behind the belt. The velocity of the water is checked, and if the trees be close enough together, they hold up brushwood and other flotsam brought down by the flood, all of which helps further to check velocity and to make the river drop its silt. The result is the quick creation of a high river bank which, by reason of its being bound together by the trees embedded in it, is much stronger than any artificially constructed *bund*. Further, the water spreading out behind the trees drops silt which eventually raises the surrounding country, thus making it practically impossible for the river ever again to cut deeply into its banks.

The sandy *manjha* areas found lower down the Ganges and Gogra rivers are admittedly a greater problem, and afforestation here would be more difficult. It would probably be necessary to start by afforesting at some little distance from the river, and gradually to advance towards it. The task, though difficult,

is nevertheless practicable—it is only a matter of experimentation to find out the best technique.

It is clear, however, that work of this kind would have to be on a very large scale, and it may reasonably be asked whether financial considerations may not render it impracticable. As we have seen, the Provinces of Bengal and Bihar are deeply interested in the question of reafforestation, and are trying to take under State management as many as they can of the forests at present under private management. The U.P. has a land management scheme in view involving a million acres for the creation of fuel and fodder reserves, the work to be spread over 10 years. The total area involved in these schemes is however small compared with the total area of the Provinces concerned.

In his note on Post-war Forest Policy, Sir Herbert Howard gives figures of areas in India available for afforestation. The following table gives, in square miles, the areas for the three Gangetic Provinces.

Province	Area	Cultivated	Uncultivated		Forests
			Cultivable waste	Not available for cultivation	
U.P.	1,06,189	60,639	15,608	15,450	14,492
Bihar	69,242	41,078	8,006	9,835	10,323
Bengal	76,966	45,956	8,990	15,015	7,005
Total	2,52,397	1,47,673	32,604	40,300	31,820

The grand total of uncultivated land for all three Provinces is 72,904 square miles. In the absence of a detailed survey, it is not possible to say how much of this area would require to be afforested. The area includes every type of land ranging from rocky mountain slopes to small patches of usar on the plains. It is safe to assume that a small proportion of it will be incapable of growing any kind of vegetation: a fair proportion of it will be incapable at present of growing trees, though it will support some form of grass or scrub, and of the remainder a large proportion will be required for grazing areas.

We are left therefore to make only a guess at the total area required to be afforested with a view to minimum river stabilisation. Authorities seem to be agreed that roughly about 25% of a country's area should be under forest, assuming that the forests are correctly distributed. This gives a rough figure of 60,000 square miles. The figures show that nearly 32,000 square miles is already under forest of some kind, though much of it is badly managed, and a great deal more is forest in name only. Of the remaining 28,000 square miles,. if we assume that half requires to be planted with trees, the balance being reserved as grazing

grounds, we arrive at an empirical figure of 14,000 square miles, or roughly one fifth of our present uncultivated land.

A rough check on this can be made. There are, as we have seen, a total of about 29,600 miles of sizeable river in the Gangetic system in the three Provinces. Including the smaller streams which are not included on a small-scale map this figure may well be doubled. Assuming that 50% of the total area requires afforestation and that on the average half a square mile of forest per mile of river is required, we arrive at the figure of nearly 15,000 square miles which comes near enough to our first figure. The area in question already includes some afforested area in the Himalayas, but as against this, there are stretches several miles deep of ravine country requiring attention in certain riverain areas, so that the figure of 15,000 may be adhered to.

The above estimate, though little more than a guess, nevertheless shows the magnitude of the task. The cost is bound to be colossal.

It is extremely difficult to arrive at any possible figure of cost. So much depends on local conditions and the state of the soil. Estimates of the capital cost naturally vary considerably. The U.P. Land Management scheme is worked out on a basis of Rs. 5 per acre, exclusive of the cost of acquisition. This figure represents the net loss per acre at the end of ten years. The total expenditure is 25% more than the above figure. Even so, the estimate is much smaller than anything I have seen elsewhere. The Etawah ravines, according to F. Benskin, Deputy Conservator of Forests, cost in 1915-17 Rs. 60 per acre to afforest. Figures of Punjab *bela* afforestation are given by a Forest Officer in the *Indian Forester* of June 1945, as Rs. 90 per acre. Mr. C. F. Simmons, I.F.S., late President, Forest Research Institute, Dehra Dun, who kindly gave me assistance on the subject, emphasises that it is impossible to estimate hypothetical cases with any accuracy. The main factor, he states, is whether one really has a soil —not merely eroded land with the surface soil missing through sheet erosion. Another important factor is the human one—the skill of the man in charge in respect of the right species and plantation technique. Mr. Simmons has however given as possible minima and maxima Rs. 50 and Rs. 250 per acre, or Rs. 32,000 and Rs. 1,60,000 per square mile.

An average maintenance cost is even more difficult to assess. Mr. Simmons puts it at something between Rs. 25 and Rs. 50 per acre or Rs. 16,000 to Rs. 32,000 per square mile for the first ten years. Maintenance costs naturally drop as the forests get older,

though the costs for the first ten years or so are fairly constant. After the trees reach a certain size, intensive weedings, climber cutting and cleanings are no longer required. Costs are reduced if the small stuff removed in thinnings can be sold. Mr. Simmons has known teak plantations in ideal teak soil on the bank of a river pay for themselves in 10-15 years ; but we cannot reckon on such a return, since our soil conditions and sites will in many cases be far from ideal. Mr. Simmons considers that at a very rough figure, Rs. 500 per acre for the first ten years, or Rs. 3,20,000 per square mile would be a reasonable average estimate.

It needs no emphasis to show that the cost of afforestation at the above rates is enormous ; needless to say, it could not be attempted all at once, but would require to be spread out over a period of fifty years or more. Even so, the outlay is very great, and though experiments in land reclamation, both in the U.P. and the Punjab, have, as a rule, been financial successes, it by no means follows that such measures will be so in every case.

Much of the financial problem, however, will be solved if the forests so grown can be made merchantable. This is where inland navigation will be of the utmost assistance. As we have seen afforestation for the purpose of preventing water erosion, must be done in the riverain areas. No method of transport for large logs and baulks of timber is cheaper than water transport. The economic implications will be discussed in the next part: meantime the intention is merely to draw attention to the fact that development of river transport as a State monopoly constitutes the best chance of the State to find the money necessary not only to carry out these schemes of land management on a large scale, but to make them remunerative to an extent to which they could never otherwise hope to attain.

II. The Economic Aspect

We have already seen some of the economic considerations affecting river transport. Briefly summarised, these are that river transport, as it exists today, is in general an extension of seaborne trade into the interior of a country ; and that, where industrial conditions exist on the river-bank, it will pay to develop water transport even where navigational conditions compel transhipment at river mouth.

Primarily, the development of industry depends on the cheap transport of fuel. Though electricity can provide power, it is not so convenient or economical as coal for the production of heat for

certain industrial processes. For this reason such industries as paper, food, metals, glass, earthenware, etc., which require heat as an essential part of the process of manufacture, will always prefer coal. The cheap transport of coal, therefore, is a prime essential to the development of industry in areas far from the coalfields.

In this connection, the example of the Rhine industries is of the utmost interest. Prior to 1875, this industrial area was little developed, and the greatest attraction for travellers on the Rhine was its romantic scenery and ruined castles. Between 1875 and 1900, in spite of the fact that the existing industrial areas were already linked by rail, the German Government undertook a programme of river improvement and artificial waterway construction at enormous expenditure, the exact figures of which, according to Consular Reports, are not available, but which have been estimated at not less than a total of Rs. 66 crores. Some idea of the extent of the work may be guaged from the following. The Rhine and its tributaries were formerly natural watercourses of varying depth and shallow bed, so shallow, in fact, that only the smallest vessels could navigate as far as Strasbourg, 300 miles inland. The soft banks of the rivers prevented ships going at considerable speed because their wash damaged the banks. In severe winters, ice on the river frequently put a stop to all navigation for days or weeks at a time.

At the present day, the Rhine is a deep river, taking barges with a draft of 2.75 metres (about 9 feet) as far as Cologne, while vessels of 600 tons or more can navigate as far as Strasbourg. This has been accomplished by blasting the rocks in the river bed, by dredging to a considerable depth over hundreds of miles of river. The river bed has been narrowed and deepened and the natural earth banks replaced by solid masonry walls. The tributaries have been subjected to an even more radical improvement in many cases. The Main, for instance, was a shallow stream only 2¾ feet deep. It has now been dredged out to no less than 8¼ feet for a distance of 20 miles as far as Frankfurt on Main, at a cost of over 50 lakhs of rupees, and this again in spite of the fact that Frankfurt was already served by a railway parallel to the river.

The result of this bold policy was an immediate expansion of water-borne traffic, and between 1882 and 1902 the tonnage of the German inland fleet was trebled. The most sensational effect was the phenomenal increase created in the demand for coal from the Dortmund district. This increased steadily so that the production rose from a little under 12¼ million tons in 1870 to nearly 60 million tons in 1900. Transport of coal still forms a very large percentage

of the Rhine barge traffic, and this transport would be impossible were it not for the cheapness of inland water carriage as compared with that by rail. Even more sensational is the increase of traffic of Hochfeld-Duisburg-Ruhrort, the principal industrial area of the Rhine, which rose form 2.9 million tons in 1875 to 13 million tons in 1900.

From the above it can be seen what an enormous expansion of industry followed as a direct consequence of the improvement of the Rhine waterways. The main reason for the expansion becomes evident when it is realised that, at the above period, the capital cost of a barge of 2000 tons capacity ran out about Rs. 33 per ton, while a railway wagon of ten tons capacity cost about five times that amount per ton of load room. Mr. O. Eltzbacher, in an article in the *Contemporary Review* of December 1904, quoted in Mr. Pointon's monograph above referred to, gives actual figures of comparative costs of transport of coal in Germany by rail and waterway, and shows that this is roughly from 50 to 115 per cent higher by railway than by canal only, by canal and river, or by railway and canal. It must be remembered that at this period the freight rates on the Prussian State Railways were probably the lowest in Europe. It is therefore little wonder that Mr. Eltzbacher concludes that if it were not for the existence of the German waterways, German industries would not be in the flourishing condition in which they were at the time of his writing.

So far as India is concerned, industrialisation in areas close to the Ganges rivers is as yet, with the exception of the Bengal iron mines, the Damodar coalfields and Cawnpore, either non-existent or very poorly developed. External seaborne trade via Calcutta was, before the war, considerable, but, in the main, the imports consisted largely of manufactured goods, while the exports were chiefly raw materials. India, however, is acknowledged on all hands to be about to enter on a period of industrial development. If we add to this the fact that Japan's industries have been crippled as a result of the war, and that all the vast markets of the Far and Near East are open to Indian manufactures, it will be surprising if industrial development does not lead to a considerable development of overseas exports. At the same time, there will be stimulated an import trade, first in capital goods, secondly in those raw materials which are not available in India, and third, in those consumer goods which for some time to come will still not be manufactured in the country.

In some respects India's industrial problem is unique. Though she possesses vast resources of coal and iron, these are found con-

centrated in certain areas, of which the chief is to be found in Bihar and Bengal. For iron-smelting limestone is required, but though supplies of this are, for all practical purposes, unlimited, they are not found in the near vicinity of the iron deposits. The Gangetic valley has already shown its suitability for certain types of industry, notably textiles, paper, leather, sugar and plywoods. The problem of power for these industries can very largely be solved by the development of hydro-electric resources, but it would be idle to pretend that electricity can entirely displace coal. In certain industries, for example, paper pulp manufacture, heat is a prime requirement, and hence it is much more economical to instal boilers and steam plant for the entire process of paper manufacture, since the same coal can provide steam for both stages.

It is therefore necessary for the proper development of industry in the Gangetic valley that a cheap form of transport be developed, such as would be provided by improved riverways. Not only so, but, in order that the industries of the Eastern Provinces be adequately provided with raw materials such as limestone, hides, grain, timber and cotton, a cheap downstream transport is just as necessary.

This brings us to the question of railway competition and this is a matter which must be very carefully considered.

Right at the outset, it must be emphasised that there must not and cannot be any question whatever of developing water transport at the expense of the railways. The railways are an essential asset for the economic safety and well-being of the State, and any move which would tend to weaken them cannot be countenanced, if for no other reason than their security value in times of national danger. But, in any case, as will be shown, water transport itself depends to a very great extent on the parallel development and prosperity of the railways.

Parallelism of the European rivers by railways has been mentioned. Some of them, notably the Rhine, are very closely paralleled by railways throughout their entire length. The effect of this parallelism, and the lessons to be learnt from it will be of considerable interest.

In the first instance, it may be explained that in Western Europe, including Holland, Belgium, France and Germany, there existed long before the railways, a network of river and canal waterways, all of which were maintained by the State and which were extensively used for navigation. When railways were developed, most of these too were State-owned, and therefore it was possible for the State to control development policy. The position

was entirely different from England where a system of privately owned canals was in existence before the railways. The latter were also privately owned, and their first act, on coming into existence, was to fight tooth and nail to destroy their rivals .The outcome of that struggle was a complete victory for the railways, and the almost entire ruination of the canals, much to the detriment of many of Britain's industries.

On the Continent, by contrast, it was the deliberate policy of the State to devote a portion of the profits of the railway system to development of the waterways. The results may be seen from the following extracts from Consular Reports to Parliament, August 1903, and other sources, for which I am indebted to Mr. Pointon.

As regards Belgium, the Consular Report states—"It may justly be claimed that in providing the country with a system of navigable waterways and cheap transport, in multiplying the points of contact between road, rail and water transport and thus facilitating transhipments, in rendering the seaports easier of access and in stimulating the erection of numerous commercial and manufacturing establishments, this work of improvement (of the waterways) has been one of the principal factors of the commercial prosperity of the country."

Actual figures give a more accurate estimate of the extent of commercial prosperity. Between 1875 and 1900 Belgium spent Rs. 12 crores approximately on waterways improvements. In 1880 traffic on the waterways was 22.5 crore tons per mile: in 1900 it was 56 crore tons per mile. On the railways traffic in 1880 amounted to 1.4 crore tons, and in 1900 to 4 crore tons —an increase of nearly three times, while in the seaports the increase of tonnage over the same period was from .5 to 1.7 crore tons.

As regards Germany certain figures have already been given showing the increase in coal production following the improvement of the Rhine waterways. The increase of traffic was however, by no means confined to coal alone, and here also the freights carried by the railways showed an increase. Mr. S. A. Thompson, in an article in the *Engineering Magazine*, July, 1902, quotes the American Consul-General, Mason, as reporting to his Government in 1897 that the Rhine river traffic, which amounted to only 1.5 lakh tons before the improvements were made, had increased to 7 lakh tons in 1896, while the traffic by rail which amounted to 9.3 lakh tons in 1886, had risen to 14 lakhs in 1891 and to nearly 16.4 lakhs in 1896, *being nearly double what it was ten years before, when*

the railways had a practical monopoly of the freight business of Frankfurt.

The American Consul-General went on to say—"If further testimony on this general topic were needed, it would be found in the steady growing prosperity of the railways of Prussia, which from their location are brought into the most direct competition with the principal waterways. During the fiscal year 1896-97 the Prussian railroads earned $247,381,970, and the budget estimate, always conservative, for the present year (1897-98) is $264,000,000 from the same source ...... That a portion of this surplus should be devoted each year to extending the canal and navigable river system is in furtherance of a policy the wisdom of which time and experience have fully confirmed."

Mr. Thompson, speaking of France, quotes French official circles as saying:—

"It is conceded that waterways and railways are destined not to supplant, but to supplement each other. Between the two there is a natural division of traffic. To the railroad goes the least burdensome traffic, which demands regularity and quick transit ; to the waterways gravitate the heavy freights of small value, which can only be transported when freights are low."

M. de Freycinet and the French Legislative Committee, whose words these are, then proceed to put the matter neatly in a nutshell as follows—

"Waterways, by increasing traffic, are rather the auxiliaries than the competitors of railroads. In procuring for manufacture cheap transportation for coal and raw materials, *they create freights whose subsequent transportation gives profits to the railroads.*"

The truth of the above proposition has been amply proved by continuous and frequent example not only in Western Europe, but in America, where the development of freight traffic on the Mississippi river has been noted. On the Mississippi it is interesting to note that though parallelism by railroads also exists, the nature of the river traffic has completely changed. In former times passenger traffic formed a great part of the transport on that river: whereas now bulk cargoes form 98% of the total traffic.

At this stage a word of caution is required. While it is not intended to derogate from the general proposition that improvement in waterways is a powerful stimulus to the development of industry, it must be remembered that there is another factor to be considered—a factor which, in Europe, because of its being taken

for granted, is apt to be overlooked. The factor to which I refer is technical advance in the equipment of water transport.

The question of equipment and the importance of the speed factor will be more fully discussed in the next chapter: meanwhile it is necessary to point out again that the carriage of goods by water can be successful only where the minimum requirements of bulk and speed are met. Improvement of the waterways is only one of the ways in which these requirements can be ensured ; the other is up-to-date design of barges provided with mechanised haulage.

In Europe and America the early application of the steam engine to water-borne transport enabled technical advance on the waterways to keep pace with that on the railways. The railways were in the long run helped and not hindered. Competition between two different forms of transport can cause a decline in one of them only if the technical advance of one form lags behind that of the other. This happened in India, but it did not happen in Europe.

The subsequent invention of the internal combustion engine and its application to marine haulage further improved the position of the latter in comparison with the railways, particularly in those countries where oil itself formed a cargo. In 1904-05 Nobel Bros of St. Petersburg (now Leningrad) built two vessels each 250 feet long to carry about 800 tons of oil from the Caucasian oilfields across the Black Sea and up the Volga. These were powered with Diesel engines each of 360 h.p. and were the first vessels of their kind. Their success led to the rapid development of the motor ship, to such an extent that nowadays, all oiltankers are so powered, and an increasing proportion of the world's shipping in other branches of trade is going over to this form of propulsion.

The internal combustion engine however had its greatest field of opportunity in developing road transport—the last of the modern world's three main systems to be mechanised. The application of the I.C. engine to road haulage so enormously improved its efficiency in its best sphere, namely, transport over comparatively short stages of haul, that it was bound to, and did at first, attract from the railways a considerable amount of local traffic. But this, contrary to opinion at the time, was an ephemeral effect only. The increased efficiency of road transport increased correspondingly the efficiency of the railways, not only by cutting down the cost and time of transhipment and delivery between railhead and destination, but also by extending greatly their area and scope of

service. So much was this so, that the railways in Europe and America could not now do without mechanised road haulage even if they wanted to, and it is more than likely that improved road haulage has by now brought more traffic to the railways than ever it took from them.

In general therefore the respective characteristics of water, rail and road transport are that water is the best medium for bulk cargoes of 1000 tons or more consigned to a single destination ; the railroad is best for smaller consignments in respect of which distribution is also a factor ; while road transport is most efficient where the bulk involved is very small and convenience of distribution is the main consideration.

In practice these ideal considerations are not achieved, for the simple reason that waterways exist only where Nature has arranged them, or made them possible ; and in such a country as India the exigencies of water supply and other engineering considerations make very doubtful any large extension of artificial waterways. Thus, even if the existing riverways are fully developed, the railways in India will still have to shoulder the task of distributing the bulk of India's supplies.

It is clear however that rational development of the waterways of the Gangetic plain will be of great ultimate benefit to the railways. Cheap transport of power commodities such as coal and fuel oils, and of raw materials such as pig iron, timber, industrial oils etc. will enable India to overcome, to a large extent, the existing maldistribution of her resources, principally by reducing the effective distance between the sources of power and those of raw materials. The effect of this in promoting rapid development of industrialisation in the entire Gangetic valley cannot be over-estimated. Industrialisation in turn means for the railways, not only increased distributional traffic in manufactured goods and in consumer goods to the industrial areas, but also increased traffic in bulk freights to and from areas not served by the river. In short, anything which helps to expand industry increases the flow of traffic and thereby all forms of transport are benefited.

As we have seen however, this desirable coordination of traffic will occur only where there is a possibility of State control. Private enterprise knows nothing of ultimate benefit to the State, or even to itself: all it is concerned with is immediate dividends. In India, happily, we have reached a stage where the railways are State-owned and directed, and road transport is in the process of being coordinated into companies in which the State and the railways together will be the principal shareholders, and over which

effective State control can therefore be exercised. It is necessary therefore that a similar control be exercised over water transport: it will never do to revert to the chaos of petty 'one-man-one-boat' ownership. The example of road traffic should be sufficient ; yet there appears to be, in certain official quarters, blindness to this danger. Unless control can be exercised, there is every possibility of competition between petty shipping companies, or single boat owners, leading to the same rate-cutting policy which the railways found so devastating in the case of road traffic before the war. It may be pointed out however that waterways are not roads: if a rate-cutting campaign were started, the railways would be in a position to retaliate ; and there is no question, in my opinion, as to which would be in the better position to do the other damage. River transport does not, and cannot possess the flexibility of rail transport, and the railways could easily kill an infant water transport, not only by rate-cutting to an extent with which the latter could not hope to compete, but also by refusing to allow facilities for transhipment. This matter will receive further attention in the chapter on organisation.

It has already been emphasised that there is no question of developing water transport at the expense of the railways. It still remains to be emphasised that even if this salutary policy were disregarded river transport can never hope to succeed by merely filching a share of the general cargo at present carried by the railways between places on the river-bank. The volume of such traffic could not in any circumstances provide an adequate return on the capital investment involved. It is idle also to suppose that the present inadequacy of the railways for the transport needs of the country constitutes a permanent opportunity for the development of river transport: this is an abonormal phase which will shortly come to an end as soon as supplies of rails and rolling stock are again available to the railways.

In short, it is necessary to discover and develop types of cargo which, on account of the high rates of transport or of technical difficulties involved, either cannot be handled at all, or cannot be fully developed on the railway. The search for such cargoes is particularly necessary in order to tide water transport over the interim period between its inception and the growth of industry which may reasonably be expected to develop in consequence.

Some of the types of cargo suitable for river transport are cotton, ore, metal, coal, wood, fuel and industrial oils, grain, chemicals, fodder, wool, potatoes, cement, limestone, leather, salt,

sugar, machinery, oilseeds and manufactured goods packed in large bales or boxes.

All the above classes of goods are at present handled by the railway, but it is possible to select a number of them which are particularly of a nature such that the railways cannot economically handle them over long stages of haul. Such cargoes are ore, pig-iron, timber in long lengths, fuel oils of low flashpoint, fodder, cement, limestone and machinery of such dimensions as to cause difficulty in sideways or overhead clearance on the railways.

The above list contains many important items in the list of commodities essential for industrial areas. It will, I think, be well understood that these commodities are either those in which the cost of freight by rail is too high in relation to their intrinsic value to allow of a large volume of traffic, or they possess some characteristic such as inconvenience of dimension or danger in handling which requires the use of special equipment on the railway. It is clear that in the case of commodities of low commercial value, there is a limit beyond which the railways cannot offer a favourable tariff, and the same applies to the other class of commodities mentioned. Special equipment means increased capital cost and increased running expenses: it is small wonder then that the railway carries logs, for example, only in limited quantities ; and in regard to machinery, the freight by rail from seaport is sometimes prohibitively high.

The policy for river transport must therefore be to develop first those commodities which the railway is unable to handle, and thus to ensure that the latter system suffers as small a drop as possible in the amount of freight carried until such time as expanding industry makes up for the temporary loss. This theme will be developed later in this chapter, and certain cargoes will be specified as having particular interest in this connection.

It is clear that if we are to enjoy the full benefit of cheap transport of bulk cargoes from sources of raw materials to manufacturing centres and *vice versa*, we must avoid transhipments as far as possible. The principal area for pig iron and steel production in India is Tatanagar. The centre of the Damodar valley coalfield is Raniganj. The centre of industry in the United Provinces is Cawnpore. None of these places is at present open to water transport. Tatanagar and Raniganj are at long distances from the Gangetic rivers, while navigation up the Ganges to Cawnpore, as has been shown, is no longer practicable.

The first essential therefore in any comprehensive scheme of

waterways development is to consider ways and means of linking these important centres with the main Ganges river by means of artificial cuts. There appears *prima facie*, no reason why this should not be successfully accomplished. Tatanagar is about 75 miles as the crow flies from Midnapur. Midnapur is at present linked to the Hooghly by the Midnapur High Level Canal, which is at present navigable by power vessels at certain seasons of the year. It should not be too difficult to extend this canal as far as Tatanagar utilising as far as possible the waters of the Subarnarekha river to replenish the canal. The Midnapur canal itself would, of course, require to be improved in order to make it navigable throughout the year, and this should not present a too difficult engineering problem, particularly since an inexhaustible supply of water exists in the Hooghly from which enough for navigational purposes can be pumped in the dry season.

Raniganj is about 65 miles in a straight line from the nearest part of the Bhagirathi river. It is situated on the Damodar river, which, though not navigable in that section, will form a valuable water supply for a navigation canal running between Raniganj, Burdwan and the upper Hooghly somewhere just above Hooghly town. The present plan of the Bengal Government to dam the Damodar should ensure an all the year round supply for navigational purposes.

Similarly a navigation canal from Bahramghat, the natural terminus of navigation on the Gogra river, to Cawnpore via Lucknow, a total distance of about 60 miles, should not present any great difficulty. Apart from pumping from the Gogra at one end and the Ganges at the other, such a canal could be supplied at its central section from the Gumti river.

These artificial extensions to the navigation system of the Gangetic rivers would be of the greatest benefit. The foundries of Cawnpore could be supplied with pig-iron from Tatanagar and coal from Raniganj at the necessary cheap rates, while the limestone of the U.P. and Bihar could be transported to Tatanagar in return.

A further downstream cargo which has very special interest is timber. As has already been stated, it is not economical to carry long lengths by rail. A typical pre-war freight rate for sal is 8 annas a maund for a distance of at least 500 miles, for a consignment of not less than 400 maunds. But on account of various interpretations of the railway rules, and the fact that at least half of a log goes to waste in sawing, the net cost of freight per cubic foot of good timber is not less Re. 1, and may be more than double

that figure. Present prices of sal timber in the log vary from Rs. 1/8 to Rs. 2/4 per cubic foot* if to this is added the cost of handling and road freight in addition to railway freight, it can easily be seen that freight and incidental charges on timber from the East U. P. for instance may in Calcutta easily exceed its prime cost at U.P. timber depot.

Recent developments in timber utilisation, particularly in conjuction with plastics, have enormously raised the status of this material in the world of engineering. Plywoods and laminated woods have been improved beyond all recognition, while patent compressed boards of the Masonite type and "compregnated" wood open up an entirely new field of use in industry.

Principally these developments have been made possible by the development of plastics—synthetic resins of the phenol and urea-formaldehyde types. The use of these resins as fillers between layers of thin wood and other materials, such as paper, has only begun, but will increase enormously in the next half-century. The most interesting of these layered materials is compregnated wood, which consists of layers of thin veneers with plastic resin between—the whole being compressed into a hard, tough material of much greater density than wood, and practically impervious to heat, moisture or decay. Such material is superior to metal for many purposes.

The manufacture of all plastics starts from a cellulose base. The raw material at present most favoured for this purpose is cotton linters, of which India produces an adequate supply. Cellulose can be made from wood also, particularly soft wood, but there is at present some difficulty in obtaining pulp of sufficient purity for the manufacture of plastics. It is however certain that this difficulty will be overcome, and the subject has an important bearing on the question of Indian timber.

The last century has seen an enormous increase in the demand for wood of all descriptions in European countries. The great bulk of this demand is for soft woods, principally for house construction, packing case materials and general carpentry. By far the greatest import of wood products however, is in the shape of paper pulp, for which the demand is ever increasing. The growing use of plastics will further enormously increase this demand for wood pulp, just as soon as a method has been devised for obtaining the necessary purity.

It is common knowledge that the forests of North America and Scandinavia, the two principal producers of softwoods, have

*Government controlled price in 1946.

for years been felled at a rate much greater than the rate of regeneration. Recently, the timber trade of Britain and the U.S.A. have been at pains to deny rumours that there will be a shortage of timber as a result of the war. Supplies, they say, are ample. This is quite true, but it does not alter the fact that the softwood forest resources of the world are being slowly eaten into faster than they are being replaced. Shortage may not begin to appear for another fifty or perhaps a hundred years, but it is quite certain that the present rate of consumption cannot continue unless more is done to ensure quicker regeneration than at present.

One thing is certain, that prices of softwood will rise. It will be difficult to predict the extent of this rise, but any rise which does occur will be to the advantage of countries which will be in a position to export large quantities of tropical hardwoods.

The substitution of hardwood for softwood will not be an easy process. The building trade prefers the latter for its easy workability, and ease of fastening as compared with hardwood. The same considerations apply to all hand carpentry operations. But the use of hardwoods is bound in time to increase. Naturally there are at present many uses for which hardwoods only are suitable, and still more for which they are preferable. Chief among these are marine uses, such as pier-work, fenders etc. In addition there is shipbuilding and furniture manufacture. Even at the present day, no material has been found to displace wood for the decks of ships—even battleships and aircraft carriers have their decks of this material. In aircraft construction plywood has particular advantages where lightness and speed are prime desiderata. For house construction, particularly prefabricated houses, timber has special application, while for superior furniture hardwoods and hardwood veneers are in ever-increasing demand.

The invention of special types of timber connectors and their development during the present war has enabled the field of use of timber in the civil engineering sphere to be very greatly expanded. The inherent weakness in joining comparatively short lengths of timber in a large span has to a very great extent been overcome, and towers 400 feet high and roof spans of well over 200 feet clear are now practical possibilities. Demand for timber therefore for civil engineering projects is bound to increase.

In India it is certain that any increase in industrialisation will mean a very greatly increased demand for all classes of timber. During the war the Government forests have been overfelled, and any great increase of supply from that source cannot be expected.

As has been shown, there has been, during the war, ruthless felling of private timber, and supplies from that source are also unlikely. The result is that the present small import of softwood into Calcutta from the U.S.A. and Scandinavia, ridiculous though it is, will probably be enormously increased in a period of industrial expansion. In short, India will, like Australia, have to import timber because of neglect to conserve her own forests.

Great extension of the present forest areas is urgently needed for soil conservation purposes. Some idea of the urgency and the vast extent of the work and expense has already been given in Chapter 5. One of the main difficulties in the way, as has been pointed out, is the difficulty of making such schemes productive of direct revenue to Government. Afforestation as we have seen, is required chiefly in the riverain areas, and, in general, these areas are of two kinds : the headwaters of the rivers, and the alluvial riverbeds. Naturally forests in such areas have little chance of being merchantable with our present systems of transport. One cannot build railways in the mountains, nor roads in areas liable to flooding. But the establishment of a modern system of water transport will solve that problem most effectively. In many cases it will be possible to float timber (in this case chiefly softwood) down the mountain streams, as far as the place where navigation proper can extend. As for forests in alluvial tracts, no difficulty in applying water transport can possibly arise.

In short, with the demand from industry, and the provision of cheap transport with little, if any, transhipment, there are the brightest hopes of any scheme of anti-erosion afforestation becoming in time directly productive of a very considerable revenue to the State. Little fear need be had of over-production. There will always be a strong and increasing demand from outside countries for cheap and good hardwood. If an example is required, it exists in Burma. It is a mistake to regard Burma teak, for instance, as necessarily superior to Indian. In the days when East Indiamen were built in Calcutta, Malabar teak was accounted superior to the Burma article both for ribs and planking. The reason given was that in the larger sizes Burma teak was frequently spoiled by reason of heartshakes. Balfour, writing in 1843 makes particular mention of this fact. This defect does not now appear in Burma teak logs, and was due to improper seasoning. Nowadays the Burma teak industry has been organised by the Burma Forest Department to such an extent that it is assured that only perfect timber, which has undergone a period of seasoning of five or six years, shall reach the port of lading. Were it not

for this organisation, the superiority of Burma teak in the timber market would certainly not exist.

By contrast, in India, though there are many excellent timbers available, it is extremely difficult to get seasoned wood for any purpose. Even where there has been a certain amount of seasoning, the timber is frequently spoiled by improper methods. This is a great pity, since Indian hardwoods are second to none for certain uses. For example, it has been established by rigorous research in the Forest Research Institute, Dehra Dun, that sal, shisham, babul, kikar and khair are superior to Burma teak for certain marine requirements, including durability, resistance to parasites, bending stresses, shearing strength and shock resistance. It only requires organisation to overcome the defects in the present system of marketing Indian timber to make the trade in it as profitable as that of Burma teak.

In addition to timber, there are many forest products which can be developed on a large scale both for home consumption and for export. One example of this is Indian kapok, which is the silky floss obtained from pods of the semal tree (Bombax Malabaricum). This material is superior to any Java kapok, which at present is in commercial demand as a stuffing for lifebuoys, lifebelts and other nautical life-saving appliances as well as stuffing for pillows and mattresses. The semal tree itself is used for the manufacture of cheap packing cases and for match splints.

I have gone into the question of timber at some length, since I am convinced that the development of water transport is the solution of the problem of financing the vast schemes of afforestation necessary to reduce soil erosion to such an extent as will ensure that agricultural production will be sufficient to ensure an adequate food supply to the developing industrial areas. Conversely, I firmly believe that the timber traffic alone resulting from such a scheme would go a long way to support a water transport system without any outside aid.

Traffic on any river, however, cannot have its best chance of success unless it operates both ways—upsteam as well as down. A special upstream cargo must be found, and it exists, in my opinion, in Burmese rice (as an upsteam cargo for timber barges) and Burmese oil.

The special feature of these cargoes is the distinct possibility of extending our river navigation at certain seasons to include the coastal passage to Akyab and possibly other Burmese ports, thus doing away with transhipment between there and all river ports as far as Cawnpore. I have been assured by a prominent oil fac-

tory owner, R.B. G. M. Modi of Modinagar, that any system of transport which would make possible the transport in 1000 ton lots of crude oil direct from Burma to refineries in Cawnpore would have instantaneous success. This however would depend on whether the Burmah-Shell Oil Company would be prepared to export from Burma crude as opposed to refined oil.

If such cargo is possible (and there is no reason why it should not be) a corresponding downstream traffic in tank barges would be vegetable oil. At present much of the eastwards traffic is in the shape of oilseeds. A saving in transport space of at least 30% would be possible by the substitution of oil for oilseeds on this route. Greater employment in India would result in the case of oil intended for export, and further the cost of the oil would be cheaper. There is no technical difficulty in carrying mineral and vegetable oil in the same tank barge.

Oil is a commodity which the railways are incapable of handling economically. Tank wagons are limited in size so that the unit of bulk per axle is small, Tank wagons moreover, particularly in the case of oils of low flashpoint, are specially costly. Precautions against fire or explosion have to be stringent, since damage and risk to human life in a crowded goods yard might be very great. Shunting and storage have to be arranged with special precautions, causing delay and expense in handling, in addition to increased organisational costs. Further, railway transport involves the construction and maintenance of large and costly storage tanks at docks into which tankers discharge their cargo ; and lastly the loading of railway tank wagons from these storage tanks is a slow and inefficient business. Where oil is carried in tins there is even less efficiency. It is certain that the demand for kerosene and light oils generally would greatly increase in the upper Gangetic plain if cheaper oil could be ensured by bulk transport and (if necessary) subsequent refining at Cawnpore.

The above represent some of the economic possibilities for river transport. It must again be emphasised that the possibilities above envisaged in all cases postulate a modern fleet of river craft with power propulsion or towage. In the above scheme of things the country boat has no place, and no chance of success. A very great deal depends on the selection of the right equipment. This will be our consideration in the next chapter.

CHAPTER VII

ORGANISATION

The organisation required is of two characters ; the first being that necessary to survey the possibilities, choose the best type of equipment, and select and establish the best operational system; and the second, that concerned with the running of the operational system after its establishment. The latter is itself capable of division into two main branches—the technical and the commercial. The first deals with the deepening and maintenance of water channels, and construction and maintenance of vessels and wharf equipment: the second with the commercial organisation connected with the shipping of goods, and the development of trade on the rivers.

The essential features of an inland water transport system, as we have seen, are facility of internal carriage of raw materials to industrial areas, and development of export and import trade beyond the coasts of India. In the case of internal trade there are possibilities for coal and iron ore upstream with limestone and timber downstream in exchange, while for seaborne export and import trade I have suggested mineral oil and rice as main import cargoes with timber and vegetable oils as main exports.

It is clear that if these desirable ends are to be attained the river and its organisation must be regarded as a single transportation unit. Nothing less than a single unifying policy can be considered. This can be achieved either by Central Government legislation or by a coordinated policy adopted by the three Provinces concerned with or without the general direction of the Government of India.

Legislation is the first requirement. According to the Seventh Schedule of the Government of India Act 1935, read with section 126, the Federal legislature alone has power to make laws in respect of shipping and navigation on tidal waters, Admiralty jurisdiction, major ports, transport of petroleum and other dangerously inflammable liquids and substances, and import and export custom duties. The Provincial legislatures alone are empowered to make laws governing inland waterways (other than in respect of mechanically propelled vessels) ports other than major ports, water supplies, irrigation and canal drainage and embankments, water storage and water power, production, supply and distribution of goods, dues on passengers and goods carried on inland waterways and taxes on boats. The Federal and Provincial legislatures have

concurrent legislative powers in respect of shipping and navigation on inland waterways as regards mechanically propelled vessels, the rule of the road on such waterways, and the carriage of passengers and goods on inland waterways.

In regard to the development of industries, this is a Federal subject, where development under Federal control is declared by Federal law to be expedient in the public interest ; otherwise development of industries is a Provincial concern.

Under section 103, if two or more Provincial legislatures resolve that any of the matters in which the Provinces alone have jurisdiction should be regulated by Federal law, the Federal legislature may pass an Act accordingly, but such law can at any time be repealed by a single Province in so far as it applies to that Province.

The position as regards legislation is therefore complicated, no fewer than four legislatures being involved. In general, all matters connected with navigation on the rivers, whether tidal or non-tidal, whether by power vessels or not, including such matters as buoyage, pilotage, the rule of the road, control of river ports, carriage of goods and deepening and maintenance of channels will require to be regulated by a single act to be called the Inland Navigation Act. Other subsidiary matters, such as afforestation, land conservancy measures, and development of trade and industry can conveniently be legislated for separately. An Inland Navigation Act can be passed only by the Central legislature, under the above provisions of the Government of India Act, but how far the Provinces will cooperate in this matter remains to be seen.

It is necessary in order to obtain speedy and certain coordination between the various legislatures involved, that the framing and administration of the Inland Navigation Act be entrusted to an Inland Navigation Commission, composed of representatives from the Federal and Provincial Governments, advised by representatives of the commercial interests involved. The Commission should also exercise an advisory function in regard to the subsidiary matters mentioned above—afforestation, development of industry etc.

The Commission, which must necessarily be a permanent one, should exercise authority in regard to navigation and river conservancy in all Provinces. It should be financed from the profits of navigation on the rivers, and should have full responsibility for deciding how and where expenditure should be allocated with a view to improving navigational conditions, or stimulating river traffic. The Commission should be responsible as a body to the

Federal Government only ; though members appointed by a Provincial Government as its representatives would naturally be responsible personally to their respective Governments that the instructions imparted to them were properly carried out.

Other than by delegation of powers to a representative Commission such as the above, there does not appear to me any practical alternative. Separate action by each Province is quite out of the question. Geographical conditions make such action impossible. It is not possible, for example, to develop waterborne trade between the United Provinces and Bengal without improving the Bhagirathi channel: but the Government of Bengal cannot be expected to undertake that duty at its sole expense, and the Government of the U. P. even less so. At present there is in any case little incentive to the Government of Bengal to improve the Bhagirathi channel, since its main importance is as a through trade route to Bihar and the U. P.; for unless these two Provinces give a guarantee that they will in return improve their own rivers and grant facilities to Bengal operators, improved navigation on the Bhagirathi is not likely to yield a satisfactory return to Bengal alone.

It is of course possible that difficulties such as the above could be overcome by a system of reciprocal agreements, whereby each Government retains independence of action over its own rivers and affords the others reciprocal facilities on a *quid pro quo* basis. It needs no argument however to show that such a cumbrous system will involve interminable delay and haggling over questions of trade privileges, allocation of expenditure, and contributory grants, all of which will operate drastically to limit the development not only of water transport, but of industry itself. In these conditions, competition between Provinces and between the Provinces and the Centre is very likely to develop, such as developed to a marked degree on the European waterways some years before 1939. In the case of the Rhine, for instance, the policy of the German Government was to divert traffic as much as possible from the waterways to the railways in order to favour the German North Sea ports at the expense of the Belgian and Dutch ports at the mouth of the Rhine. The necessity for some form of international control of riverways in Europe has long been felt, but political reasons have so far stood in the way, with effects which, in the case of certain rivers (e.g. the Danube) have been little short of disastrous. In particular, in India, if competition between Federal railways and Provincial waterways were to develop (as it is practically certain to do) there need be no doubt as to which is

the better placed to meet such competition. As I have previously pointed out, mechanised water transport as an aid to industrial development cannot exist without the railways, whereas the converse is not true, and competition between them can only end in the ruination of the former.

Assuming that we have a central co-ordinated authority in the shape of an Inland Navigation Commission, it is next for consideration what sort of water transport organisation it is feasible to set up. In the first instance it is for consideration whether a state of competition should be allowed on the waterways, or whether a monopoly is required.

Personally I have no doubt whatever as to the necessity for the latter. A co-ordinated policy of river development demands it. In the first instance the aim must be to develop long distance traffic in bulk cargoes, and to avoid competition with the railways. Such desirable objects cannot be achieved without financial guarantees by the State. Such guarantees cannot be given where loss may be occasioned by inefficient management or by cut-throat competition by one transport company against another. But the main objection to competition in transport is that involved in transhipment. It is not practicable to have a multitude of wharves and sidings at river ports ; and where companies possess limited capital, facilities for transhipment are likely to be poor or even non-existent. The chaos caused on the roads by the "one-man-one-bus" system and its detrimental effect on railway transport has been sufficiently proved. It is obvious that power transport on the rivers also cannot properly succeed if the transport organisation has to face a multitude of petty competitors all anxious to undercut rates in the case of special consignments where the absence of the necessity for forwarding or transhipment arrangements permits them to do so.

On the other hand, the existing river steamer companies have almost exclusive possession of all the technical knowledge and trained manpower available to run a water transport system. In the formation of any organisation, they must of necessity be included as an integral part. Probably the best solution will be to link these companies up with the state and the railways, (as was recently proposed in the case of road transport) to form a single company, partly state-owned, with a monopoly of all traffic on the river.

If a full monopoly is not achieved, and privately owned river craft are to be permitted to use the rivers and compete with the State-promoted company there will, in my opinion, be a serious

waste of effort, which may have a disproportionate retarding effect on development. Apart from that there will be an operational problem created by their use of the river. For example, they will have the benefit of the buoyage and pilotage organisation, which they will have paid nothing to establish. It will therefore be for consideration whether they are to be permitted to avail themselves free of the State navigational facilities or pay their share of the cost. If they are to pay, this will postulate some form of dock or river dues. The cost of collection of such dues is likely to be disproportionately high. There is moreover one invisible asset which they will be able to derive, namely, an increased share of trade resulting from general development of water transport for which the State organisation will have to bear all the expense. It will not necessarily be the case that increased trade will lead to greater profits per boat, since the country boat is not of such a type as to admit of more efficient use than at present. The benefit of increased trade will largely be absorbed in the high operating cost of these boats, to the detriment of all concerned. Further, if competition is to be permitted at all where will it stop? What, for instance, is to prevent a group of capitalists from building a fleet of barges and tugs, taking advantage of the navigational facilities which the State organisation has set up? Even if they are made to pay their share of maintenance, the saving to them in initial cost would be enormous, and their competition would be a most serious matter, particularly as they would naturally restrict their operations to the most fertile ranges ; skim the cream of the trade, so to speak. Lastly there must not be forgotten the complications arising out of damage and loss by collision with private vessels, or by their stranding and blocking navigable channels, or by their colliding with buoys. Such damage may be considerable, and it may not always be possible to trace the vessel responsible, and even if it is traced, the owner may not be in a position to pay even a fraction of the damage or loss.

In short, there can be no doubt whatever that the ideal would be to establish a transport monopoly on the rivers, but whether this policy must in practice be modified, and to what extent, is a matter for decision. It might be practicable to allow existing traffic to continue in its present ranges of operation, or possible to restrict private craft to certain types of cargo. Both these arrangements would entail a system of trade under licence. Third party insurance would be a practical necessity. Their share of the cost of navigational facilities could be paid for partly by licence fees and partly by river dues payable either on tonnage of the

boat or by a levy per ton on cargo actually carried. The former system commends itself as the cheapest tax to administer, and giving least chance of evasion.

It will be seen that I do not advocate the system of State organisation so far as navigational facilities are concerned, and the grant of monopoly licences to individual companies for navigation in fixed ranges of the river, or for particular cargoes the whole length of the river. Such a system will certainly never pay, and once started, it will be most expensive to buy out. Under such a system there must be competition which is inevitably wasteful. In particular the administrative difficulty in stopping competition with the railways would be very great indeed. Disputes would require a number of permanent tribunals, and the cost of this can easily be imagined. None of the companies would have sufficient capital to establish a service which for efficiency could approach that of a single State service as a means of developing industry in the areas served. Similarly with private capital the temptation is irresistable to encourage only those industries which provide commodities most paying from the technical point of view, and to discourage others. That such a policy would be extremely detrimental needs no argument.

It remains to be emphasised, before leaving this subject, that machinery must be devised to ensure the greatest co-ordination between river, rail and road transport. A Federal authority is required to be arbiter in case of dispute between these three transport systems, and in deciding such disputes the authority should be empowered to direct the payment of annual compensation payable by one system to another in respect of cargo formerly carried by one and allocated to another wherever this course may be justified. In general, river ports must be fully linked to both rail and road systems to facilitate transhipment and the greatest attention must be paid to this important point.

Next in importance comes the question of maintenance of navigation and equipment.

The first essential is a complete survey of the whole riverine system, for the purpose of compiling up-to-date statistics as to navigable channels, depths of water, speed of currents, nature of bottom, nature of river bank, width of channels, existing road and rail communications, wharfage and so on. Next, it is necessary to lay off the rivers in sections or ranges, according to the particular characteristics and nature of action required.

The information compiled regarding a particular range will require to be kept up to date by periodical re-survey and incorpo-

rated into a series of "Pilot" volumes. A system of buoyage and pilotage will have to be devised. For example, in the U.K., channel buoys, regarded from seawards, are, on the starboard hand, conical in one colour only ; on the port hand can-shaped, in another characteristic colour, either single (Scotland) or parti-coloured (England). Spherical buoys, striped vertically or horizontally, are used to mark spits or banks intervening between channels or middle grounds. The actual system devised does not matter greatly provided that the buoys are of distinctive shapes and colours. If lighted for night navigation the lights should be of different colours or combinations of colours. To assist navigation in difficult channels, a system of leading marks to provide transits for the helmsman may be devised, the same marks to have lights or combinations of lights for use by night. A rule of the road is required, and here it will be advisable to adopt the international rule, with such local variations as circumstances may compel. Distress and other signals must be prescribed and compiled in the appropriate place in the Pilot book.

The staff and equipment required to carry out the work involved will stand in the same relation to the general transport system as the signalling and permanent way inspectorate in the railway stands to the general railway system. This staff will require a fleet all its own—the fast motor launches referred to at the end of the previous chapter. Inspection of buoys and lights, and the taking of soundings—a daily duty in the rains—will be the main part of these duties. It will be seen that in the rains there will be a great seasonal increase in activity in this respect, and it is to be considered whether any means can be devised to cheapen the organisation. It might, for instance, be possible to utilise a part of the pilotage service during the dry weather on the annual overhaul of barges and equipment, and this is a matter which has distinct possibilities.

The construction and maintenance of vessels is the next matter for consideration. There is little to be said in this respect—the general lines are the establishment of building and repairing yards at convenient places. If wooden vessels are to be used, it will pay to establish yards as near the source of supply of timber as possible, but if steel barges are used, the yard or yards would be at the lower end of the river. In considering wood construction it is necessary to remember that if the barges are to be taken into tidal waters the presence of shipworm is a constant danger, but on the other hand most worms are killed by a 48-hour immersion in fresh water.

The work of overhaul of vessels is likely to proceed to nearly all seasons of the year, and the most important thing will be to determine the extent of the service in order that there shall be sufficient facilities for vessels to be overhauled and put back into service without unprofitable delay and that on the other hand the staff should not be so numerous or the equipment so much that either stands idle for prolonged periods. Here again speed of work will save initial cost, since it is a simple matter of arithmetic to see that if a vessel takes a month for her annual overhaul and a minimum of 24 vessels are required to be continuously in service, then a total of 26 vessels are needed ; but if the time of overhaul is reduced to 2 weeks, then only 25 vessels are required. Whether it will pay thus to speed up the work and to what extent will depend on the relation of initial to maintenance costs of vessels.

The same considerations apply, more or less, to upkeep of wharfage and wharfage equipment. In particular, it will be advisable to maintain accounts by such a system as will show the comparative efficiency of wharves and equipment, in order that there may be no doubt or hesitation in making a decision as to whether it will be cheaper to abandon an old wharf deserted by the river, or to bring the river to the wharf by dredging operations. In this connection the possibilities of prefabricated engineering equipment are to be kept in mind.

The organisation on the technical side is fairly straight-forward, but on the commercial side, not so easy to devise. First of all, cargoes will be of three main commercial characters—first those which are carried in great bulk from seaport to upriver port without intermediate handling ; second, smaller bulk cargoes of localised range of transport, and lastly general cargo. In the first category comes, e.g. timber carried in bulk from forest to sea, or oil carried from Burmese port to upriver depot. In the second class is, for example, a consignment of grain carried from up-country port to Patna or Calcutta. The third consists of small mixed consignments between river ports or for shipping abroad at seaport.

Each of these types of cargo requires different organisational treatment. In the first class we shall be dealing generally with large export or import companies whose prime consideration is cheapness of transport. In this class it is not expected that the railways will attempt to compete, but the aim must be to develop a system for the efficient carriage of commodities which the railways, for technical reasons, are incapable of handling efficiently or at all. In the case of these cargoes sailings will be by arrangement with

the shippers and, generally speaking, ample notice of dates of loading or delivery will be given. Speed therefore will not be a prime consideration but it will be desirable to adopt the speed which will be cheapest from the economic point of view, remembering from what has been said in the previous chapter, this is not necessarily, the most economical from the technical point of view. The chief requirement is to estimate beforehand how many vessels are needed in order that the available number are kept moving, and in this respect it will probably be possible to arrange a definite time-table with the shippers (who will, in general, always be the same) to cover a definite period in advance, as regards movement of cargo. This will be a very great advantage, and will make possible much more accurate pre-estimates of cost than would otherwise be possible.

The second class of cargo brings in new considerations. Generally speaking, for this class there will be a seasonal peak period (particularly in the case of grain cargoes) which, after the experience of some seasons, it will be possible to assess with reasonable accuracy. It will not, however, be possible to be certain of long notice in advance, and short notice and variable local demand may be accepted as the rule. In this class of cargo speed of delivery is of more importance, since prices of commodities fluctuate, and delay in carriage may render this class of transport too speculative to be popular with buyers or sellers. To overcome delay therefore it may be necessary to have a larger percentage of vessels in reserve. Further, the vessels in general use for this form of transport will, in general, be smaller than those used for the first class, since local charters will be for smaller cargoes, and it will not pay to sail half-empty. It is also for consideration how far it will pay to carry cargoes for two different destinations in the same vessel, since delivery of one cargo is bound to be held up while the other is being unloaded. The economy of speed in wharfage facilities is here illustrated in another way, since, if one vessel can be used in place of two, we save the wages of a crew. It is in this sphere that the barge-train appears to have special application.

From what has been said, it will be concluded that this form of transport is likely to be more expensive per ton-mile than the first class, which is in accordance with general experience. But an off-setting factor is speed, for which charterers are likely to be willing to pay to a certain extent. Putting the matter in another way, charterers are likely to pay more for a system which will give certainty of delivery within a period of such short duration as to safeguard them against loss by price fluctuations during the in-

terval. On the whole this type of cargo will be the most speculative.

The third class of cargo is in most respects the most difficult to deal with because, without some idea of the nature or bulk of consignments likely to be carried, it is not easy to lay down even general principles. For example, should the total quantity be small, it is doubtful whether it would pay to carry it at all, and it is quite possible that a policy of discouragement would be best. It must be remembered that we do not wish to compete with the railway, but (a) to develop new cargo and (b) to take in existing water transport. Such small share of the general railway traffic in small consignments as may come our way will be merely incidental, and in general we should avoid undertaking to carry a class of cargo which requires a special type of vessel and a much higher ratio of organisational cost than either of the other two types.

If we are to carry this type of cargo, it postulates a regular service system. It will probably not pay, at least to begin with, to run a single service over the full range of the riverine system. It will be safer at least to run services over limited ranges of the river, increasing the number and range of these services where traffic justifies this course. The greatest difficulty will always be in the case of small consignments which have to be consigned onward from one range to another. The amount of handling is likely to be costly, and the risk of delay, damage and loss proportionately higher. The solution is a combination of services over long and short ranges, but this would depend on the bulk of traffic. I cannot foresee that the bulk will, to begin with, be sufficiently great, since the number of big towns on the river bank is at present very small, and small consignments are certainly not capable of standing the cost of transhipment from rail or road to boat and *vice versa*. It is of course possible that in time we may see industrial centres grow on the river bank as a result of development of water transport, but it would not be prudent to build too much on that possibility.

The problem therefore resolves itself into the necessity for considerable research at the start to see whether the expected volume of traffic is such that it would be definitely worth while to construct the necessary equipment, and establish the extra organisation. It has also to be considered whether this bulk of traffic would consist mainly or altogether of traffic at present carried by the railway, and, if so, whether it would be good policy to take away this traffic, particularly if it were substantial. In consider-

ing the railways we are not altogether altruistic. It has to be considered that freight rates are not stable, that economic conditions may come into being which may render this type of traffic unprofitable, and that if we once take this traffic from the railways, it will not be an easy matter to get rid of what has become an unprofitable burden.

In short, it once again requires emphasising that the proper course is to adopt a discouragement policy in respect of traffic which can be more efficiently carried by rail, and any encouragement policy in respect of such traffic should be restricted to that which at present either cannot be carried except by water because of lack of railway transport facilities of any kind, or which, because of places of export and import being situated on opposite banks of the river, or on railways of different guages, or both, cannot profitably be handled by the railway. From the national point of view anything which savours of competition is wasteful, particularly if it involves double sets of equipment to do the same job and both running to half capacity, and both belonging to the State.

Many of these considerations have application also in the case of passenger traffic. Here speed is paramount, even in third class traffic, but great cheapness might attract a considerable number of passengers. For this form of traffic very special equipment is required, and the majority of the traffic, except in special areas, e.g. the Sunderbans, would be stolen from the railways, neither of which considerations is desirable.

At this stage we come to a consideration of what is probably the most important aspect of all in regard to organisation—that which might be termed the liason aspect: this includes first, relations with public services (e.g. municipal services) where these exist ; second, relations with that section of the public (e.g. shippers) who use water transport ; and third, relations with the world at large—in fact, what might be termed propaganda and publicity services.

The first of these raises important questions. First of all it is for consideration whether dock and wharf areas should be excluded from the operation of municipal law, as in the case of railway property. If so, some arrangement will have to be come to as regards municipal water and electricity supplies. Exclusion will also impose certain responsibilities of sanitation, road maintenance, storm water drainage, maintenance of river banks, etc. The latter question is likely to give rise to complications. For example, what control are the Commissioners to have to prevent the private owner of property on the river bank above or below their wharf

from constructing a wall or embankment in such a way as to cause danger from resultant scour or silting? Such danger may also ensue from neglect of existing private riverside property. The procedure to be applied in such cases and the financial implications involved require to be thought out with care.

As regards public services, where these already exist, the question is merely one of suitable arrangements for supply. But there are few large towns nowadays on the river bank, and there will be many wharves situated at road ferries and railheads where there are no such services at present in existence. Here the problem is to provide such services. Water may not be a problem so far as supply is concerned, but drinking water will in many cases not be obtainable close at hand except from the river, or at best from kachha wells in the vicinity. This raises questions of water purification, and it must always be remembered that increased river traffic will increase the danger to the country as a whole of waterborne epidemics. Electric supply may also be a problem, and where this cannot be had from a public supply, it may be necessary to have a different source of power for driving cranes, pumps and dockside machinery. How far this will add to operational costs is a matter for investigation.

As to relations with that section of the public using river transport, questions will arise regarding such matters as dangerous cargo, right to refuse shipments, public safety, realisation of dues, acquisition of land, exclusion of the public from wharf premises, powers to prevent damage to wharf property by private property owners in the vicinity by either acts of commission or omission, measures for the safety of barge crews and transport employees generally, rule of the road and use of roadsteads and anchorages.

In the matter of publicity, no particular difficulty exists in bringing the water transport organisation to the notice of that class of person it is most desirable to attract, namely, the big commercial or industrial magnate in India. But it is also necessary for the purpose of export trade, to publicise the project among shipping companies and agencies and importers and exporters of foreign countries. Particular attention requires to be paid to the facilities for transhipment to be afforded to seagoing vessels at river port. If the volume of mid-stream transhipment tended to cause congestion in the river at Calcutta, it might be feasible to divert upcountry export and import traffic to some special port such as Port Canning.

In regard to the general development of industry and commerce as a whole, it will be necessary to provide for full and fre-

quent interchange of views between the organisers of the three transport systems, and industrialists or commercial men who wish to erect factories or develop any particular form of trade, so that the best facility of transport may be made available in all cases. In particular, the development of forests and the timber trade should be in the forefront, and for this, special co-ordination with the Forest Department is essential.

It has not been possible to do more than touch upon the various essentials in organisation. The work is immense, and will require to be directed by men of technical knowledge, capacity and foresight. There is however, I believe, a great future for the Gangetic riverine system as a transport highway, provided it is developed with judgment and care, and for India it should be a particular pleasure that the sacred river should afford yet another means of furthering the wealth of the nation.

CHAPTER VIII

THE MILITARY ASPECT

In 1905, Mr. Bramley, Superintendent of Police, Benares, in a report to the Governments of what are now the U.P., Bihar and Bengal, urged as one of the paramount reasons for rehabilitation of inland water transport its usefulness in time of war. "It will," he wrote, "assure the maintenance of an indestructible auxiliary line of communication to fall back on for military purposes in times of national danger, where the Railway services were interrupted or in need of augmentation."

These words were truly prophetic. It needs no elaboration to convince everyone today how much better India would have been able to meet the extraordinary demand for war transport in World War II if she had kept alive and developed her inland navigation.

Though there is little reason to expect that a threat of invasion of India's eastern frontier will recur in the near future, nevertheless it would be folly to imagine that such a situation will never again arise. Marshal Stalin in a speech on November 6th 1944 put the case clearly. Referring to the necessity of disarming Germany he said.

"It would however be simple-minded to think that she will make no attempt to regain her strength and embark on fresh aggression. Every body knows that German rulers are already preparing for fresh war. History shows that a period of 20 to 30 years is enough for Germany to restore her to power." He went on to characterise Japan also as an aggressor nation, and then said,

"It is a question not of personal qualities but of aggressor nations interested in war, nations preparing for war over a long period and accummulating power for that purpose, who usually, and in fact, are bound to be better prepared for war than peace-loving nations who are not interested in starting wars. This is natural and clear. It is a historical truth which it would be dangerous to ignore. So it cannot be doubted that one day the peace-loving nations may once again find themselves caught unprepared by aggression unless they elaborate now special measures to prevent aggression."

How true these words are will perhaps be realised only when the threat of a Japanese invasion again recurs. If they require corroboration attention is directed to the Tokyo broadcast to the fighting fronts informing Japanese troops of Japan's surrender.

It said, "We have lost, but this is temporary." It went on to say that Japan's mistake was "lack of material strength and necessary scientific knowledge and equipment. This mistake," went on the broadcast, "we must amend." The meaning and threat are clear.

It is remarkable how quickly a nation forgets the past: the idea of rivers as an aid to movement, instead of an obstacle, is, in India, practically dead. Even among our military leaders at the beginning of the war there were few, if indeed any, who fully realised the military importance of the rivers of the Gangetic plain. When the Japanese stood at the borders of India, both at the Assam border and near the coast of Bengal, there was a general idea abroad, supported by all classes of official opinion, that if we could only hold them back till the rains, invasion of India was no longer possible till the next cold season. Perhaps this was as well: public panic was thereby averted. Why at that particular time the Japanese suddenly abandoned their special methods of amphibious warfare and confined themselves to purely land operations in most difficult terrain of the whole front will to me always remain a mystery. The only explanation I can think of is that to the Japanese if was so obvious that they could not believe the method had any surprise value. Be that as it may, it is to this inexplicable change of policy and this alone that India is indebted today for her escape from invasion.

I personally have never been of those who believe that the rains will be any obstacle to an army attempting an invasion of India from the East. The facts show quite the opposite. During the rains when land forces would find it impossible to manoeuvre at speed across rivers in the Ganges Delta or the Sunderbans, an amphibious invading force would be in their element infiltrating in small boats among the islands where they would have excellent cover from our reconnaissance aircraft. At the other end of the line, an attack through Assam is admittedly a more difficult proposition. There is only one narrow gauge railway, and no road except for that to Imphal. The difficulties of transport are enormous—except in the rains. Then one has the Brahmaputra, capable of carrying swiftly downstream and towards India the largest barges and the heaviest equipment. As soon as it enters Eastern Bengal the river obligingly turns south and flows exactly in the line an invading army would want to take up, and more than that, it links up with the army working up the Ganges Delta at its lower end.

The advantage to the enemy of this river must not be ignored.

Unless we too are equipped with river patrol boats and water transport, it would be difficult to stop his progress downstream. Air action, even where concentrated, and enjoying complete mastery of the skies, cannot effectively stop river navigation. No better proof of this exists than the escape of a large proportion of the disorganised German army across the lower Seine and the Maas during the spectacular Allied advance in July 1944. In Assam therefore where the nature of the country limits the number of airfields, it is unlikely that air action alone would be able effectively to stop river navigation on comparatively small ranges of the Brahmaputra.

Consider the case of an invading force in Assam equipped with water transport against a defending force with none. The Brahmaputra runs in the line of the advance. The commander of the invading force knows he may expect to find the defending force in one of two dispositions—first, split into two parts, one on each side of the river ; second, concentrated entirely on one bank. He then makes his plans accordingly. In the first case, he swings his whole force to that side of the river where the weaker enemy concentration is. The defending commander cannot adequately reinforce or supply the attacked portion of his army, nor cross to its support nor withdraw it to the other side. The only things he can do therefore are either to accept the risk of battle between a portion of his force and a superior enemy force, or retreat along both banks of the river. In the second case, the invader swings his whole force to the bank opposite to that taken by the defenders, and advances as rapidly as he can westwards. The defenders can then do one of two things—either stay where they are and accept the risk that the invaders will recross the stream lower down, cut their lines of communication and fall on them from the rear ; or retreat. Once the retreat has started, there is no stopping it till they reach Bengal and fall back on the line of the Teesta. This is infiltration *ad summum*.

If the invading force were able to cross the Teesta and cut or capture the Eastern Bengal Railway the defending commander would then be in an even more serious situation. He would then be in the same position in regard to the Ganges as he was with the Brahmaputra. The same three alternatives are before him. There is only one bridge—the Hardinge—and no other, road or rail, for a distance of 350 miles to his rear—right up to the U.P. border, in fact. The Hardinge is a railway bridge far from any first class road. Ferry facilities consist of country boats, but the mallahs will have fled. In any case these boats cannot carry heavy equip-

ment and are too narrow to take army trucks. The area south of the river contains the entire industrial resources of North India: that to the north is purely agricultural. The difficulties and dangers involved in splitting their force are so great that of the three alternatives the defenders would probably choose to withdraw entirely south of the river (if they could). But that would again expose them to risk of being cut off from N.W. India and being attacked in the rear. The only alternative would be to abandon Calcutta, Jamshedpur, the Jharia coalfields and all Bengal and Bihar and take up a position in the riverine area of the East U.P. standing first behind the Great Gandak and Son, then falling back progressively on the Little Gandak, the Rapti and Gogra in the north sector and on the Ganges on the south sector. That is to say, if all this could be arranged without having to abandon all heavy equipment in the process. This statement of the position is by no means fantastic. I shrewdly suspect it is more or less what actually happened on the Chindwin during the retreat from Burma.

It is recognised that one of the major plagues of the professional soldier is the amateur tactician, and it may be that all this has been thought out and provided for. But I am perturbed by the fact that practically no soldier to whom the matter is mentioned appears to realise how hopelessly inadequate (one might even say non-existent) are the present facilities for transporting an armed force across any of our major rivers in the rains or indeed at any other season.

Let us take the Gogra-Ganges river. This stream is navigable at all seasons of the year, even for medium sized craft, right from the Bay of Bengal over 850 miles up country up to a point in Lat. 26°, Long. 81° approximately, i.e., a point on the Nepal border between districts Kheri and Bahraich in the U.P. In the rains it swells to enormous proportions, being in parts 3 miles wide, and the current speed anything up to 8 knots. From the point given above it flows about 65 miles to Bahramghat where it is crossed by the B.N.W. Railway (narrow gauge). At the same place there is a road ferry suitable only for light traffic. From there it flows 165 miles—an impenetrable barrier in the rains except by boat—to the next railway bridge at Turtipar in Gorakhpur district. 50 miles further on there is another B.N.W.R. bridge at Revelganj near Chapra. Soon afterwards the Gogra joins the Ganges, and from there the combined stream, swollen by the Jumna as well, flows on for no less than 340 miles to a point east of Calcutta where it is crossed by the Hardinge bridge—the last bridge to cross it.

Four bridges in over 650 miles is scarcely an adequate provision for transport of heavy equipment (for by the present road ferries such transport would be impossible) for the support of an army in the field, but that is all there is.

Further, thanks to the policy of alleged road-rail "co-ordination" so persistently and fatally pursued by the Government of India for many years before the late war, it has been ensured that where there are railways (and of course railway bridges) there shall be found no parallel roads. This has an important bearing on the question.

One can cross a railway bridge in the usual way, that is, by train, or, if this is not possible, then by using the bridge as a road bridge. In the former case one needs facilities for loading and unloading heavy equipment. These facilities are not available except at a very few big stations. Further, owing to the same Government policy, there are very few railway stations adequately linked to metalled trunk roads. A look at a large scale map will convince anyone of this. One can nearly always find some sort of village track, but in wet weather the passage of half a dozen vehicles is enough to turn this sort of track into an impossible morass. The result is that to find anywhere to load heavy stuff would be a serious problem. Even when loaded, the stuff could not be unloaded immediately it reached the other side of the river, but would have to go miles ahead to a station where facilities for unloading and a road connection exist. The ideal, of course, would be a crane. In normal times one might find narrow-gauge cranes at the following places, though there is no guarantee about the matter.

	South of the river	North of the river
For Bahramghat	Lucknow (40 miles)	Gorakhpur (135 miles)
For Turtipar	Benares (80 ,,)	Do. (60 ,,)
For Revelganj	Do. (100 ,,)	Do. (110 ,,)
For Hardinge Bridge	Calcutta (95 ,,)	Nil

I have not taken into consideration any difficulties such as the railway line being damaged or blocked by enemy air action, or the fact that the drivers of the travelling cranes and the railway signalling staff generally will have disappeared, in all probability leaving points locked firmly the wrong way.

As for using the bridge as a road bridge, as has been said, there is usually no road anywhere within miles. Again one could probably find a village track, but it needs no imagination to realise the inevitable mass bogging that would result from the heavy

vehicles of a whole army converging on a single bridge in wet weather. A commander would be exceptionally lucky if in these circumstances he got half his wheeled transport through.

Once up to the bridge, the problem would be to get on to the track. It must not be presumed that this could always be done near the bridge. These big rivers have a habit of backing up a mile or more after heavy floods along the steep railway embankment. If vehicles cannot run on the track without any modification, would there be enough material to do the necessary conversion? Two miles of track at least must be provided for.

Nothing of course is impossible, and as a last resort one could construct an endways loading ramp on the line, and load into trucks, if one had the time, if a drop-end truck could be found (they are scarcer than rubies) if it would do to load one truck at a time, manhandle it across the bridge, unload it and bring it back again. One need scarcely mention that while all this was going on a bomb or two might be dropping on the works from the skies above.

This theme has been elaborated *ad nauseam*. It has been purposely elaborated because the fact must be hammered in that, apart from four railway bridges, for an army in the rains to cross the Gogra-Ganges which divides the whole 850 mile Gangetic plain of India in half, there exists at present no other practicable means whatsoever.

Take now the one and only pontoon bridge and the ferries. Bahramghat has been mentioned. The ferry facilities there consist of one small country boat. Motorists are advised in the U.P. Road Book to obtain full particulars of ferry boats before attempting to cross the ferry. This means that even that one boat is not always available.

The next road crossing is 120 miles downstream at Fyzabad-Ajodhya. Here we have a pontoon bridge in the cold weather and a steamer ferry in the rains. Both are of limited load carrying capacity. At the beginning of the war the bridge could not take anything heavier than an unladen bus: the steamer cannot take any thing heavier or bigger than one motor car. Heavy goods are transported in country boats, but none of those is of sufficient beam to take an army truck.

If two boats were firmly lashed together, side by side, they could probably take two trucks at a time ; the double journey occupying six hours (actual tested time): in these conditions ten boats (if they could be found) working night and day without ceasing would take 3 days to get across a single transport company. In

actual practice it would be surprising if they got over in under a week. *No ghat in all the U. P. has better facilities than this.*

90 miles further on there is Dohrighat on the Allahabad-Gorakhpur road. Here there is a steam ferry similar to that at Ajodhya taking motor cars across all the year round. The ferry facilities here are not any better than at Ajodhya.

Further down the river there are further ferry facilities, but no more pontoon bridges. Ferry facilities in Bihar or rural Bengal are in general not superior to those in the U.P. In short, it needs no military experience to realise that to keep an operating force of any size in the northern half of Bengal, Bihar or U.P. adequately reinforced and supplied from the industrial areas south of the river Gogra-Ganges is, with the present facilities, utterly impossible.

The position on the Gogra has been elaborated particularly, but the same conditions, practically speaking, apply to all the major rivers of North India which cannot be bridged (at certain seasons at any rate) by the R. E. using Bailey bridging or kapok or other 'patent' methods. The obvious solution is a fleet of special craft, but, as far as my knowledge goes, apart from assault boats, which are not quite the same thing, the army in India does not possess such craft, nor are its soldiers trained in the use of small boats.

There is no reason for this neglect of the river facilities of the Gangetic plain, and there is still less reason why those very rivers which are at present almost insuperable obstacles to the efficient manoeuvring of our forces, should not be turned to our advantage. Nature has in this matter given us one inestimable advantage. This is that, with the sole exception of the Brahmaputra, all the rivers named flow in the direction of our desired advance, and against that of the enemy. This means that, in the cold weather, we have 3-4 m.p.h. added to the speed of our laden boats bringing up supplies and reinforcements, and in the rains anything up to 8 m.p.h. while the enemy has this to contend with. For the benefit of optimists let me point out that his advance will not be checked by this—it will merely be rendered slower. Again our boats return light against the stream, and his go light with it—unless, of course, he is in retreat, when we descend to nothing worse than level terms.

It is therefore necessary, now, to make provision for the necessary water transport, and to train as many men as possible in embarkation and disembarkation, and in handling boats on the

river, Fortunately, as will be shown, the first problem is not difficult, and as river-craft is not sea-craft it takes a very short while to teach a man how to handle a boat sufficiently well for all practical purposes.

From the military point of view, there are four main aspects of the river question. They are:—

(1) Use of rivers as an auxiliary means of transport ;
(2) Provision of adequate ferry facilities to enable reinforcements, equipment and supplies to reach forces on the other side of large rivers ;
(3) The transport of infantry to strategic points not readily accessible to rail or road transport ;
(4) the establishment of a "mosquito" fleet of light fast motor boats, or in other words, a river patrol trained in "anti-infiltration" tactics.

Let us take up first, (1) *The question of transport.*

It is not necessary to argue at length the comparative advantages of road, rail and river transport. For military purposes speed is paramount, and economy, except perhaps in fuel, of secondary importance. There is no doubt whatever that road and rail transport are much quicker, and the transport of goods on inland waterways is enabled to compete with land transport in point of cost only by the carriage of the greatest possible bulk at a time. This proposition may, on account of the need for dispersal, be undesirable from the military point of view. Smaller barges, carrying up to 250 tons of cargo are however perfectly feasible. The use of rivers for transport may therefore be limited by circumstances. But nevertheless in war one cannot afford to neglect any advantage, however small.

The main disadvantage of roads and railways is their comparative vulnerability. Particularly is this the case with railways. Generally speaking, our railways in the Gangetic plain lie more or less end on to the line of an attack from the East. It is by no means improbable that a number of culverts over a number of miles might be destroyed or damaged by enemy action, and even allowing for the most efficient engineering and speed of repair, it is quite possible that repair might be a matter of days, weeks or even months. On the other hand, no amount of bombing can block a river like the Ganges : in fact, heavy bombs might even help navigation by blasting out a deeper channel. In certain circumstances therefore river transport as an alternative to a damaged road or railway, even though strictly limited, might make all the difference.

(2) *Ferry facilities.* I have already elaborated this question and need say no more about it here, except to say that craft of a very special type will be required to carry the heavy loads required on a small draft. It is fortunately reasonably easy to design rafts capable of carrying loads up to 20 tons or more on a draft of less than a foot and the hulls of such rafts will be capable of being quickly, cheaply and satisfactorily constructed by the ordinary country carpenter. At least a thousand are required: double that number would be better. Power could be supplied by special vessels designed to tow or push as required. If there are enough of these ferry rafts the speed of loading of the troops, tanks, guns, trucks and equipment is limited only by the length of the river bank available.

These rafts moreover could be used for transport of supplies up and down stream where possible or necessary in addition to boats specially built for that purpose. It would be possible to construct these rafts so that two hulls could be readily attached in order to deal with exceptionally heavy or bulky machinery, or detached to enable them to negotiate exceptionally narrow channels.

(3) and (4) *Infantry transport and River Patrol.* I take these together because the same type of boat will be used for both purposes, the only difference being that in the latter case the boat will have a permanent crew of 6-8 men with rifles, a trench mortar or rocket-thrower, or a light automatic of some sort mounted in, yet easily detachable from, the boat.

As regards the type of craft required, it is suggested that, for training purposes at least, this take the form of a light open V-bottom boat about 21 feet overall, intended to plane at high speeds (in other words what is commonly called a speedboat). Beam can be 5 feet, and maximum draft under way three inches to six inches according to speed and load. She can be of seam-batten construction of Nepali *sal* and local *shisham*. Such boat can be light (600 lbs. approximately) yet very strong—she has to be to endure bumping on sandbanks and the vibration of the engine. She must carry up to 12 persons and still make good speed against the strongest current. These conditions will be satisfied if she is powered by a 22 h.p. outboard motor. The speed loaded will then be not less than 12 knots. Such a hull can be built by four carpenters in less than two months at a cost of about Rs. 300/-. The time taken in construction could be cut down considerably by the use of permanent jigs and machine saws and planes, which would be feasible if large numbers were being built.

Such a boat was designed and built by me for flood relief work in Bara Banki district, and proved a great success. I understand that the military later built a number of hulls from her model at Bahramghat.

Such a boat is easily handled, is difficult to capsize, is transportable by truck, can be carried bodily by her crew for short distances, can be quickly sunk in the river as a means of concealment and to prevent enemy ground fire from holing her below the waterline, can be quickly lifted and emptied again, and in fact provides the most mobile and safe transport possible for troops.

For such a vessel, the best engine is the outboard. Apart from the comparatively light weight the outboard has numerous marked advantages over an engine internally fitted. Only three need be given. Any form of inboard engine needs to be firmly fixed to the hull, so that if the boat is sunk the engine is lost too. An outboard motor requires a propeller shaft with stern tube, glands, packing, etc., all of which call for long experience in fitting, and a high degree of skilled maintenance. With an outboard all this is obviated. Lastly, if the propeller hits the ground, it or the stern gear is likely to receive serious damage in the case of an inboard installation, whereas, with an outboard, all that happens is that the engine tilts up, and even if that is not sufficient, there is usually a spring clutch arrangement enabling the propeller drive shaft to slip and thus obviate the danger of a blade snapping.

With a triple fleet of craft such as the above, an Army Commander would be not only independent of bridges, but would be completely mobile over 95% of riverine length in his area of manoeuvre. There are very few places where successful and rapid crossing could not be made, heavy equipment and all, with the equipment above described. In the cold weather of 1940-41 I navigated over 50 miles in stages in a 16 ft. outboard motor boat down the Gogra from Fyzabad, and was struck by the numerous points at which a crossing was possible ; quite contrary, it may be said, to expectation. Apart from a few places where there are small quicksands, or long stretches of dry soft sand through which trucks might find difficulty in going, or where there are continuous high banks of hard kankar, all the river is crossable without previous preparation, and with little difficulty.

As a long term policy it is necessary that the organisation of the army should include a special river force comprising men skilled in handling all types of river-craft and every kind of military and semi-military cargo. In addition all troops should be given as part of their training, regular exercises involving the

use of rivers and river-craft. It is not possible here to do more than outline these matters, but the necessity exists and the sooner this is realized, the better.

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